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EARLY TRAINING ESTIMATION SYSTEM (ETES)
FINAL REPORT

Lawrence H. O'Brien
Dynamics Research Corporation

Charles Jorgensen, Contracting Officer's Representative

Submitted by

Michael H. Strub, Chief
ARI FIELD UNIT AT FORT BLISS, TEXAS

and

Jerrold M. Levine, Director
SYSTEMS RESEARCH LABORATORY

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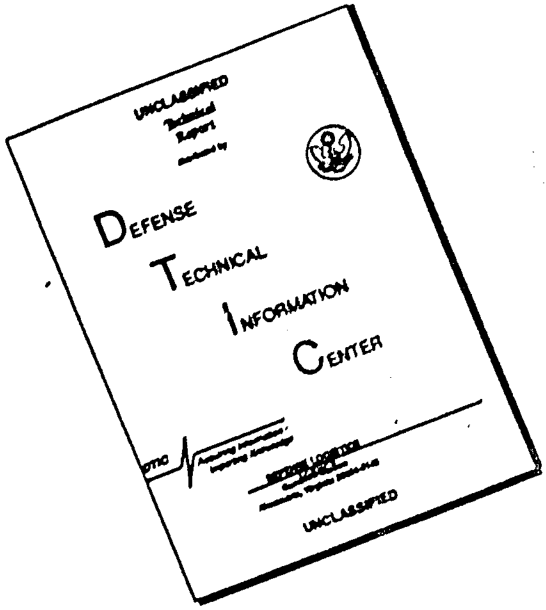

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This report describes the research and development activities conducted under the Early Training Estimation System (ETES) development project. The Early Training Estimation System (ETES) is an integrated set of procedures and automated tools for estimating training requirements during the earliest phases of the weapon system acquisition process. The ETES has three major components; a System Description Technology (SDT), Early Training Estimation Aids and Procedures (TEAP), and Evaluative Technology. The SDT is a data base management system for storing and tracking task and training-related

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data. The data in the SDT is used in the TEAP to estimate training requirements for a new system. These training requirements include estimates of task requirements, course requirements, and resource requirements as well as estimates of training costs, training efficiency, and training effectiveness. In the Evaluative Technology, the integrated impacts of training requirements are assessed, training alternatives are evaluated, tradeoff and sensitivity analyses of key parameters are conducted, and the relationships between ETES outputs and key Army acquisition documents and processes are specified.

This report provides an overview of the components of ETES, describes the research conducted under each of the five ETES study tasks; and outlines future directions for improving ETES.

The final report and Appendixes are published as separate volumes as follows:

Final Report: ARI Research Note 84-78 (includes Appendixes A through E)

Appendix F, User's Guide: ARI Research Note 84-79

Appendix G, User's Guide, System Description Technology: ARI Research Note 84-80

Appendix H, User's Guide, Media Selection Program: ARI Research Note 84-81

Appendix I, User's Guide, Automated Resource and Cost Estimation Technique: ARI Research Note 84-82

Appendix J, User's Guide, Automated Planning and Scheduling Technique for Individual and Collective Training Plan: ARI Research Note 84-83

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SECTION 1 - INTRODUCTION AND SUMMARY

1.1 OBJECTIVES

This report summarizes the research and development activities conducted during the Early Training Estimation System (ETES) project. The ETES project was a three year effort sponsored by the Army Research Institute. The objective of ETES was to produce an integrated set of procedures and automated tools for estimating training requirements for emerging Army weapons systems during the earliest phases of the acquisition process (Mission Area Analysis, Concept Exploration, and Demonstration and Validation).

1.2 ORGANIZATION

The remainder of this section describes (a) the problem areas that ETES was designed to address, (b) the intended users of ETES, (c) the ETES study tasks, (d) the components of ETES, and (e) the relationship between ETES and other ARI projects designed to assess manpower, personnel, and training requirements for developing Army systems.

Sections 2 thru 6 provide a detailed description of the research conducted under each of the five ETES development tasks.

Section 7 describes potential areas for improving the current ETES. Appendices A, B, and C describe the algorithms and software in the three automated ETES training

estimation tools -- Media Selection Program, Resource and Cost Estimation Technique and Automated Training, Planning, and Scheduling Technique. Appendix D describes other ARI projects related to ETES. Appendix E lists the Life Cycle System Management Model documents reviewed during the ETES study.

Detailed descriptions of ETES automated and procedural tools are available in the following documents:

- ETES Procedural Guide (approximately 300 pages,
- User's Guide: ETES System Description Technology (approximately 300 pages)
- User's Guide: ETES Media Selection Program (approximately 200 pages)
- User's Guide: ETES Resource and Cost Estimation Technique (approximately 100 pages)
- User's Guide: ETES Automated Training, Planning and Scheduling Technique (approximately 100 pages)

Additional descriptions of ETES tools are provided in the following technical papers:

Jorgensen, C., and O'Brien, L. The Early Training Estimation System: An automated training needs assessment technique. (Paper to be published in the first issue of the Training Technology Journal).

O'Brien, L. Automated System Description Technology. Paper presented at the Second Annual Conference on Microcomputers in Education, Washington, June 1982.

Boylston, D. An automated decision aid for the assignment of tasks to training media in early training estimation. Paper to be presented at the 51st Symposium of the Military Operations Research Society, September 27-29, 1983.

O'Brien, L. Early Training Estimation System (ETES). Proceedings of the TRADOC Developments Institute Chiefs of Analysis Seminar, October 21-13, 1981.

1.3 NEED FOR EARLY TRAINING ESTIMATION

The Early Training Estimation System provides a capability for systematically estimating training requirements for developing Army weapon systems during the earliest phases of the acquisition process (Mission Area Analysts, Concept Exploration - Phase I, and Demonstration and Validation - Phase II). These estimates of training requirements include specification of the system's task requirements, training course requirements, resource requirements, and estimates of training cost and "effectiveness."[1] There are two major reasons why such early estimates of training requirements are needed.

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[1] ETES only provides gross high level estimates of training effectiveness. These estimates are only appropriate during the earliest phases of the acquisition process.

First, by developing earlier and more accurate estimates of training requirements, the training planning process can begin earlier. As a result, the training products associated with a system, many of which require a long lead time, are more likely to be available when the system is fielded.

Second, by developing estimates of training requirements for the various design alternatives which are considered during early phases of the acquisition process, the training developer can provide the information needed to effectively influence system design.

The importance of obtaining training projections during the earliest phases of system acquisition cannot be overestimated. Most of the major design decisions related to a new system are made during the early phases of the acquisition process (see Figure 1-1). Thus, if training is to influence design, it must impact these early design decisions. And there is good reason for ensuring that training-related considerations do, in fact, impact design.

In most weapon systems, manpower costs, including training costs, are the largest component of the system's operation and support costs. Because these costs are the result of demands generated by the design characteristics of a system, acquisition policies have been established by the Federal Government to ensure that support requirements are accurately determined and evaluated in conjunction with system development (for example, the DoDD 5000 series on major systems acquisition). ETES is specifically designed to provide the Army with the capability for meeting the

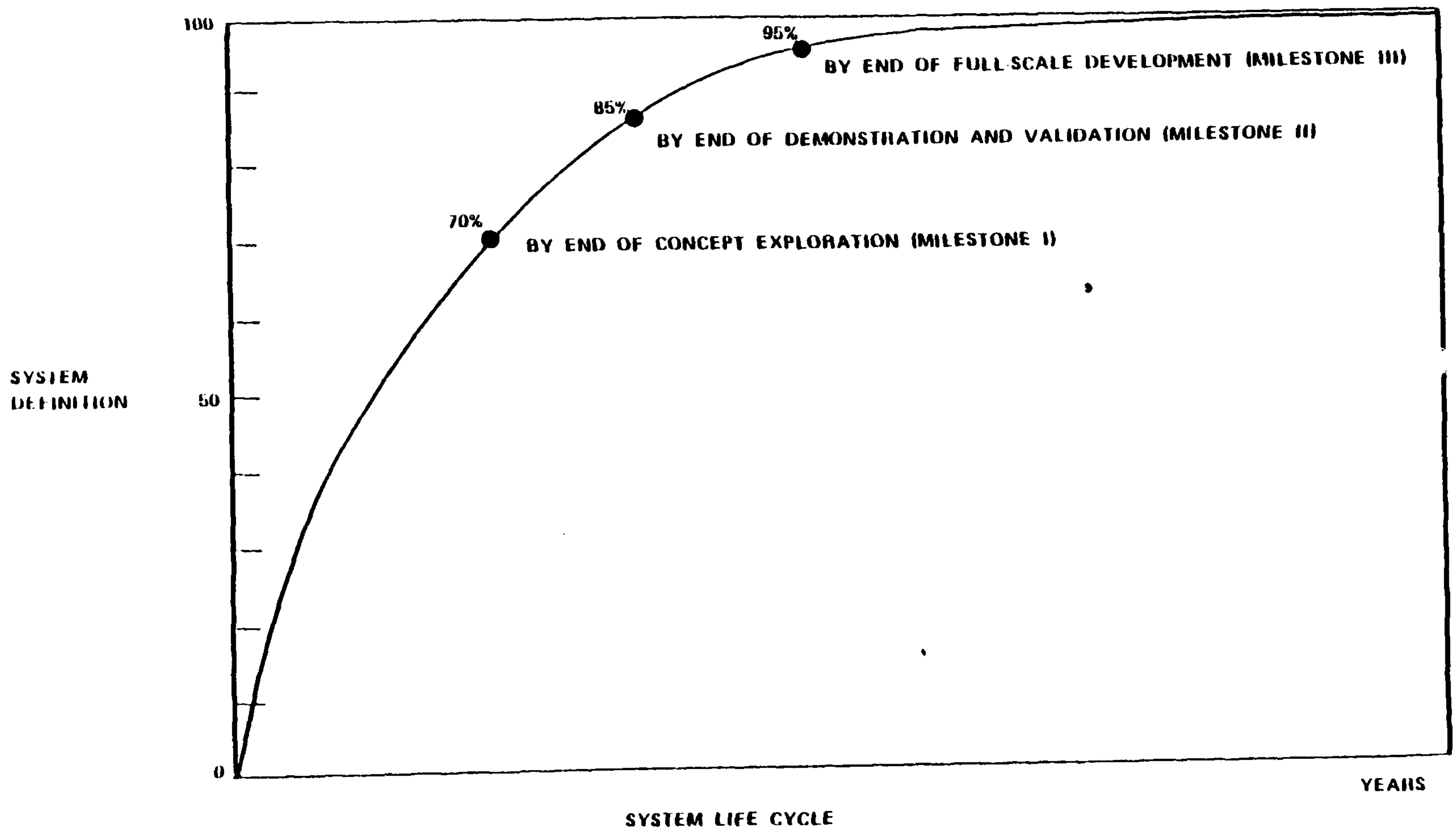

Figure 1-1. System Definition as a Function of Acquisition Phase.

training-related requirements specified in these acquisition policies.

1.3.1 Requirements for an Early Training Estimation System

As part of the first task of the ETES development project, an extensive review of existing Army capabilities for conducting early training estimation was conducted. The review identified three major problem areas which limited the Army's ability to develop early estimates of training requirements. These problem areas are:

(1) <u>Lack of Systematic Flow of Information Among Participants in the Acquisition Process</u> - Under current practices, training developers often do not receive information on system functional requirements and design concepts in any systematic format, nor are they kept abreast of changes and updates to the design concepts. In addition, there is also a large amount of redundant data development and data collection among training organizations, particularly during the early phases of the acquisition process. Army system developers and training development organizations do not currently have the full capacity to share information and this can lead to unnecessary duplication of effort. As a result, different training-related organizations often are not synchronized with each other or the prime equipment developer.

(2) <u>Lack of Estimation Procedures/Aids Appropriate to the Early Design Process</u> - Even if training developers receive accurate and timely information on early system concepts, deficiencies in training estimation aids and procedures preclude the early estimation of training resources. Most current training technologies are designed to be applied with the type of detailed data and the types of analytical questions which are more relevant to later phases of the acquisition process.

(3) <u>Lack of Systematic Technology for Rapidly Evaluating Training Alternatives</u> - Currently, there are no systematic procedures for rapidly assessing the training resources, cost, and efficiency/effectiveness of training alternatives. In addition, there are no techniques for quickly conducting tradeoff and sensitivity analyses, and asking "what if" types of questions.

1.3.2 Intended User of ETES

As part of the review of existing Army procedures conducted during Task 1 of the ETES development study, potential users for an early training estimation system were identified. The primary user organizations of ETES are expected to be (1) the training developers in the Army schools associated with the development of new systems, (2) program management offices (PMOs) for new systems, particularly those individuals concerned with training development or Integrated Logistics Support, (3) the TRADOC System Manager (TSM), (4) other Army organizations concerned with training development

such as the TRADOC System Analysis Activity (TRASANA) and PM TRADE, and (5) contractors who must develop training requirements for new systems.

1.4 ETES STUDY TASKS

The ETES development study involved five tasks. A summary of these five tasks is presented in Table 1-1. This table lists the subtasks under each task and the major products that were produced under each task. An overview of these five tasks and the original ETES concept is provided in the sections which follow. More detailed descriptions of the research conducted under each of the five study tasks is presented in Sections 2 thru 6.

1.4.1 Original ETES Concept

In the original ETES concept outlined in the statement of work, ETES was to have three components; a system description technology, a task generation procedure, and an early system simulation model (see Table 1-2). The system description technology was to consist of an "optimal language for describing developing system concepts" and an automated aid to store emerging system concepts described by the language. The task generation procedure was to provide a tool for generating task descriptions from the early system descriptions stored in the system description technology. The early system simulation model was to provide a technique for identifying and evaluating critical tasks. More specifically, the simulation model would be used to determine how system performance could be expected to be

TABLE 1-1 ETES Study Tasks

TASKS	1.0 Assess Existing Concept Development Procedures	2.0 Develop Method For System Concept Description	3.0 Develop Training Estimation Aids/ Procedures	4.0 Develop Evaluative Technology	5.0 Develop User's Guide
SUBTASKS	• Assess LCSMM-early training interfaces • Interview acquisition participants • Review/Examine psychological aspects of design process.	• Review requirements analysis tools. • Review data base management tools • Review human computer-interaction guidelines • Develop SDT • Apply SDT to Army weapon system.	• Develop training estimation aids and procedures.	• Review/examine simulation methodologies. • Develop evaluative technology.	• Develop ETES User's Guides. • Develop final report
MAJOR PRODUCTS	• General Requirements for Early Training Estimation System	• System Description Technology	• Training Estimation Aids and Procedures	• Evaluative Technology	• ETES User's Guide • ETES Final Report

Table 1-2 COMPARISON OF INITIAL AND CURRENT ETES CONCEPT

INITIAL ETES CONCEPT	CURRENT ETES CONCEPT
<u>System Description Technology</u> A language for describing developing systems and an automated aid for storing this information.	<u>System Description Technology</u> Microcomputer-based data base management system for storing information on system functional requirements, system hardware/software concepts, tasks, skills, and training program elements and their associated resources and costs.
<u>Task Generation Aid</u> Automated aid for generating task descriptions from system descriptions.	<u>Training Estimation Aids/Procedures</u> Integrated set of procedures and automated aids for estimating (1) system functional requirements and system hardware/software design concepts, (2) tasks, (3) training programs(s), (4) training resources, (5) training costs, and (6) training efficiency/"effectiveness."
<u>Evaluative Technology</u> Simulation model for linking system design changes to changes in task performance and system performance. Major output would be a listing of critical tasks, that is tasks critical to overall system performance.	<u>Evaluative Technology</u> Integrated set of procedural and automated aids for (1) developing figures-of-merit for assessing the integrated impacts of the training requirements developed in the Training Estimation Aids/Procedures, (2) identifying potential problem areas for system training and the likely sources of these problems, (3) identifying/evaluating training alternatives, which can be expected to reduce the training problems, (4) developing training-related input to key acquisition documents, and (5) determining/evaluating training development schedules.

impacted by human task performance and how human task performance would, in turn, be impacted by system design concepts.

Table 1-2 describes the current ETES concept and compares it to the original concept. More details in the current ETES concept are provided in Section 1.5. More details on the development of the current concept are provided in the sections which follow.

1.4.2 Task 1: Assess Existing Concept Development Procedures.

During this task, three major activities were accomplished. First, Army Life Cycle Management Model processes were examined to identify the key products of an early training estimation system and to identify the likely users of these products. As a result of this effort, a detailed listing of the documents, processes and output products related to early training estimation was developed.

Second, interviews were conducted with likely users of ETES to more precisely define current early training practices and needs. These interviews indicated that early estimates of training requirements (that is, estimates prior to Milestone 1) were seldom, if ever, developed. The interviews were further analyzed to identify the technical problems which contributed to the lack of early training estimation. Three major gaps were identified: (1) lack of a tool for describing and storing task and training information, (2) lack of tools for estimating what a training program should look like during the early phases of

the acquisition process, and (3) lack of tools for evaluating early training program concepts.

Third, the psychological aspects of the system design process were examined to identify the types of problem solving aids that might be appropriate for inclusion in any automated system design aids that might be developed under ETES.

1.4.3 Task 2: Develop Method for System Concept Description

During this task, five major activities were accomplished. First, automated software requirements analyses and other related tools were reviewed. The purpose of this review was to determine if any of these tools would be used as vehicle for the system description technology. The results of this review indicated that none of these tools were appropriate because (a) they were too complex to use, (b) they could not handle the frequent changes which occurred during the early phases of the acquisition process, and (c) they could not describe all of the types of data elements and data element relationships that were required for early training estimation.

When the investigation of requirements analysis tools proved to be unfruitful, a second review was undertaken to determine if an automated data base management technique could provide the technology needed for early system description. After reviewing off-the-shelf data base management systems for mainframe computers, mini-computers, and microcomputers, it was determined that a comprehensive

early system description capability could best be achieved by developing a new microcomupter-based data base management system that was specifically tailored for early system design and training program estimation. After examining existing Army microcomputer usage and the expected memory requirements for an ETES data base management system, the Apple III microcomputer was selected as the hardware vehicle for this tailored data base.

In the third subtask, recent research in the area of human computer interaction was examined to identify general guidelines for guiding the construction of SDT screens, human computer dialogue techniques and program logic.

In the fourth subtask, the SDT was developed in accordance with the general requirements for early training estimation identified in Task 1 and the human computer guidelines developed in the previous subtask.

In the fifth subtask, the SDT was applied to the Single Channel Ground Airborne Radio System (SINCGARS).

1.4.4 Task 3: Develop Training Estimation Aids/Procedures

One of the major needs identified during Task 1 was the need for the development of a set of tools for estimating training program requirements (tasks to be trained, course requirements, resource requirements, and costs) for developing systems. With this in mind, Task 3, which was originally intended to only develop procedures for task generation was expanded to include procedures for estimating (1) system functions, (2) system hardware/software and

design concepts, (3) tasks, (4) training program requirements, (5) training resources, (6) training costs, and (7) training efficiency/effectiveness.

Development of the Training Estimation Aids/Procedures began with construction of a detailed listing of the functions that were required to estimate each of these seven system elements. Existing tools which could be modified to perform these early training program estimation functions were then identified. Finally, a comprehensive set of Training Estimation Aids and Procedures consisting of both modified existing tools and newly developed tools was then constructed.

1.4.5 Task 4: Develop Evaluative Technology

The task was divided into two subtasks. During the first subtask, existing simulation techniques were reviewed to determine if these techniques could provide a systematic tool for evaluating emerging training concepts. The results of the review indicated that current simulation technologies were not appropriate for early training estimation since (a) they required data that was unavailable during the early phases of the acquisition process and (b) they could not provide output on several of the criteria (e.g., resources, requirements, costs) that were needed to evaluate emerging training concepts.

In the second subtask, a listing of the functions which must be performed in the early evaluation of training program concepts was constructed. Existing tools which could be modified to perform these functions were

identified. An integrated Evaluative Technology consisting of both modified existing tools and newly developed tools was then constructed.

1.4.6 Task 5: Develop User's Guides

Separate user's guides were developed for each of the ETES automated tools. In addition, the manual ETES procedures were consolidated into a single guide.

1.5 CURRENT ETES COMPONENTS

The current ETES has three major components; a System Description Technology (SDT), Early Training Estimation Aids and Procedures (TEAP), and Evaluative Technology (see Figure 1-2). The SDT is a data base management system for storing and tracking task and training-related data. The data in the SDT is used in the TEAP to estimate training requirements for a new system. These training requirements include estimates of tasks requirements, course requirements, and resource requirements as well as estimates of training costs, training efficiency, and training "effectiveness". In the Evaluative Technology, the integrated impacts of training requirements are assessed, training alternatives are evaluated, tradeoffs and sensitivity analyses of key parameters are conducted, and the relationships between ETES outputs and key Army acquisition documents and processes are specified.

More details on the three components of ETES are provided in the sections which follow. A detailed description of the

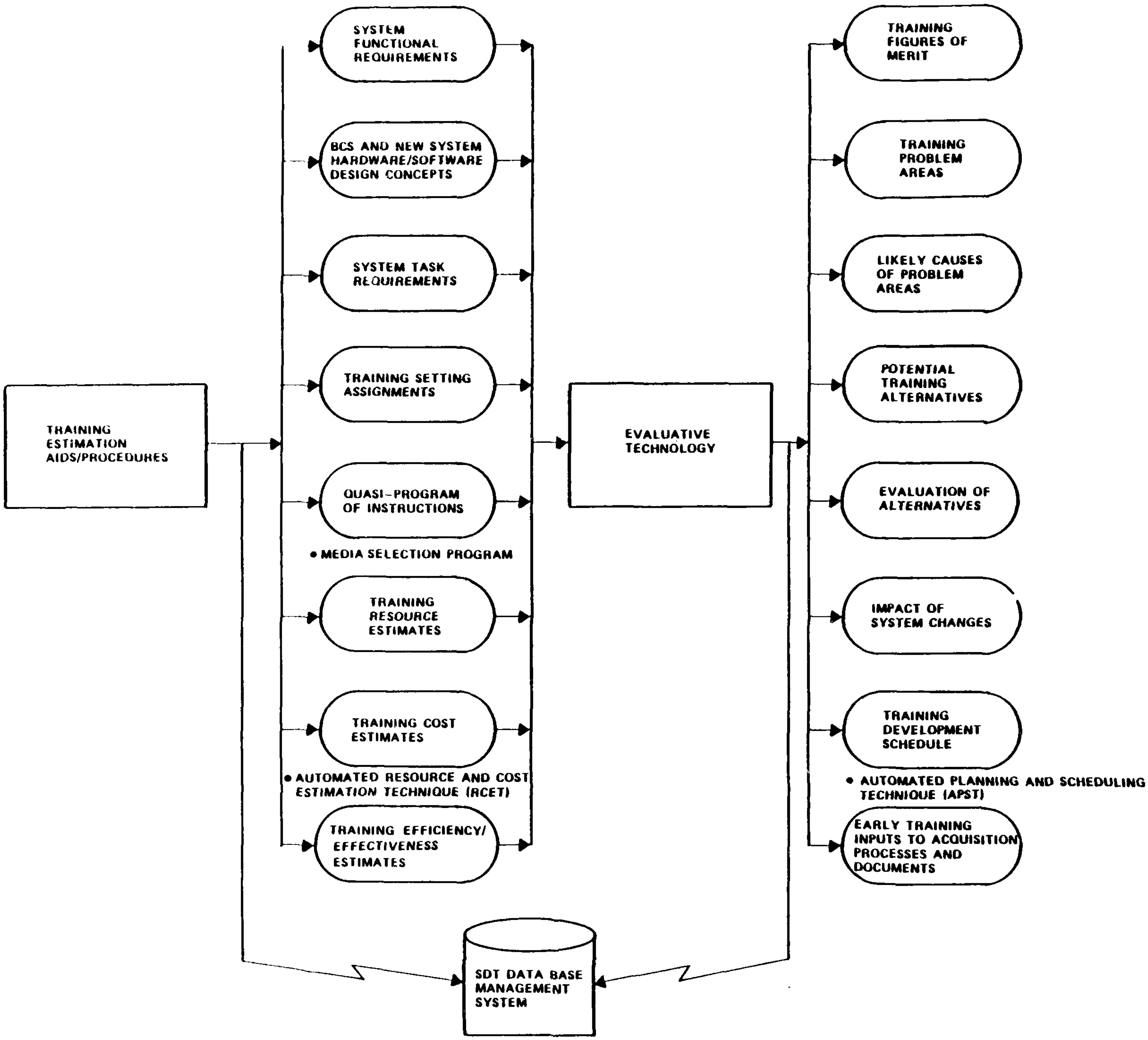

Figure I-2. ETES Components.

SDT is provided in User's Guide: ETES SDT. Detailed descriptions of the Training Estimation Aids and Procedures and Evaluative Technology are provided in the ETES Procedural Guide. Detailed descriptions of three automated tools associated with the Training Estimation Aids and Procedures and Evaluative Technology are provided in User's Guide: Media Selection Program; User's Guide: Resource and Cost Estimation Technique; and User's Guide: Automated Planning and Scheduling Technique.

1.5.1 The SDT

The SDT is a microcomputer-based data base management system for (1) describing actual and projected system elements including system functional requirements, system hardware and software concepts, tasks, skills, and training program elements and their associated resource and cost requirements, (2) for storing the above information, (3) for changing and updating this information, and (4) for transmitting the information among the participants in the acquisition process. The SDT data base management system is designed to allow training developers to keep track of the numerous system changes which occur during the early phases of the acquisition process. In addition, it provides a centralized data base, thus eliminating the redundant data collection efforts which typically take place among the numerous training development organizations within the Army.

The computerized SDT also facilitates the use of automated aids for estimating training program elements and their associated resource and cost requirements. These automated aids allow the training developer to quickly develop

training requirements estimates for alternative training and system concepts. This capability greatly increases the probability that training requirements will be effectively considered during the early phases of the weapon system development process.

1.5.1.1 SDT Data Elements

To provide an effective communication vehicle for training developers and other participants in the acquisition process, the SDT has been designed to describe (a) training programs and their associated resources, (b) the tasks which drive these training programs, (c) the personnel who will be required to perform the tasks, (d) the system designs which generate the task requirements, and (e) the functional requirements for which the system designs have been developed. An overview of the major data elements currently included in the SDT is provided in Table 1-3. Although the data elements in the SDT are designed to remain fixed for any particular application, the SDT software allows the SDT data base manager to quickly change the data elements to meet the needs of particular users and/or models.

1.5.1.2 Characteristics of SDT Data Base

Data base management systems such as the SDT use a specialized "language" to describe the relationships among data elements. Unlike many other data base management systems, the SDT does not require the user to explicitly use or even know about this specialized data language. In the SDT, the data language is made "invisible" to the user

Table 1-3. SDT Data Elements.

FUNCTIONAL REQUIREMENTS	EQUIPMENTS	DUTY POSITIONS	MISSIONS
● SYSTEM PERFORMANCE MEASURES ● ENVIRONMENTAL IMPACTS ● THREAT IMPACTS ● FUNCTION SEQUENCE INFORMATION	● EQUIPMENT BREAKDOWN STRUCTURE ● GENERIC FAMILY RELIABILITY DATA ● NUMBER SUPPORTED AT EACH MAINTENANCE LEVEL ● EQUIPMENT COSTS ● SYSTEM INFORMATION FLOW ● SOFTWARE REQUIREMENTS	● OCCUPATIONAL SPECIALTIES ● MANPOWER REQUIREMENTS (BY YEAR) ● SALARY REQUIREMENTS ● LOCATION IN ORGANIZATIONAL STRUCTURE	● PERCENT OPERATING TIME ● ANNUAL NUMBER ● ANNUAL OPERATING DAYS
TASKS	**COURSES**	**MEDIA**	
● TASK ELEMENT ● TASK CONDITION ● TASK STANDARD ● INITIATING CUES ● TERMINATING CUES ● TOOLS/TEST EQUIPMENT ● FAILURE MODES ● LEARNING OBJECTIVES ● PERFORMANCE MEASURES ● SKILLS AND KNOWLEDGES ● TRAINING EMPHASIS SCALES	● PREREQUISITE COURSES ● FOLLOW-ON COURSES ● COURSE COSTS ● STUDENT INPUT REQUIREMENTS(BY YEAR) ● MODULES –METHODS –STUDENT/INSTRUCTOR RATIOS	● COSTS ● ISSUE RATE ● TYPE OF MEDIA ● TRAINING ASSIGNMENTS	

through "user-friendly" human-computer dialogue techniques such as menu selection and question-and answering.

There are four major types of variables in the SDT data language:

- o Entities - Major system elements. Entities are roughly equivalent to nouns in the English language. The entities in the SDT are functional requirements, system missions, equipment, tasks, courses, training media, and personnel.

- o Subentities - Lower level system elements. Subentities are linked to entities in a hierarchical fashion. For example, "task conditions" are subentities of "tasks."

- o Attributes - Descriptors that delimit or specify important properties of entities. Each attribute has a set of values associated with it. Attributes are used to describe both entities and subentities. For example, one attribute for the entity "task" is "task frequency."

- o Pointer Variables - Variables used to specify the relationship which exist between different entities, between entities and subentities and between entities, subentities, and attributes. The relationships specified by the pointer variables determine the SDT data structure. (The SDT uses elements of both hierarchical and relational data base structures.)

1.5.1.3 SDT Configuration

When fully implemented, the SDT will utilize a distributed processing architecture (see Figure 1-3). A centralized data base for each weapon system (or weapon system alternative) will be stored on a mainframe computer. At periodic intervals, users will transfer a copy of the data base from the mainframe to a local microcomputer. Once on the micro, users can perform standard data base management functions (input, output, modify). Thus, all major data base management functions can be performed independently. Once users have completed their activities, they can transfer the updated version to the mainframe. A detailed "audit trail" will be kept for each weapon system so that users can systematically track and assess system changes. The current version of the SDT is designed to operate on (1) an APPLE III microcomputer with a modem, printer, monitor, floppy disk drive, and a 5 megabyte hard disk and (2) a Honeywell DPS 8/32 mainframe computer. The mainframe computer is actually only needed when there is more than one user and these users are located at several different sites. The SDT has built-in security features which allow the SDT manager to restrict data input, modify, and output capabilities to a limited set of users.

1.5.1.4 SDT Operation

To provide a user-friendly interface, dialogue on the micro computer relies on menu selection techniques for data item and command selection and data output. Form-filling and question and answer dialogue techniques are used for data input. A "help" key is provided to allow users to obtain

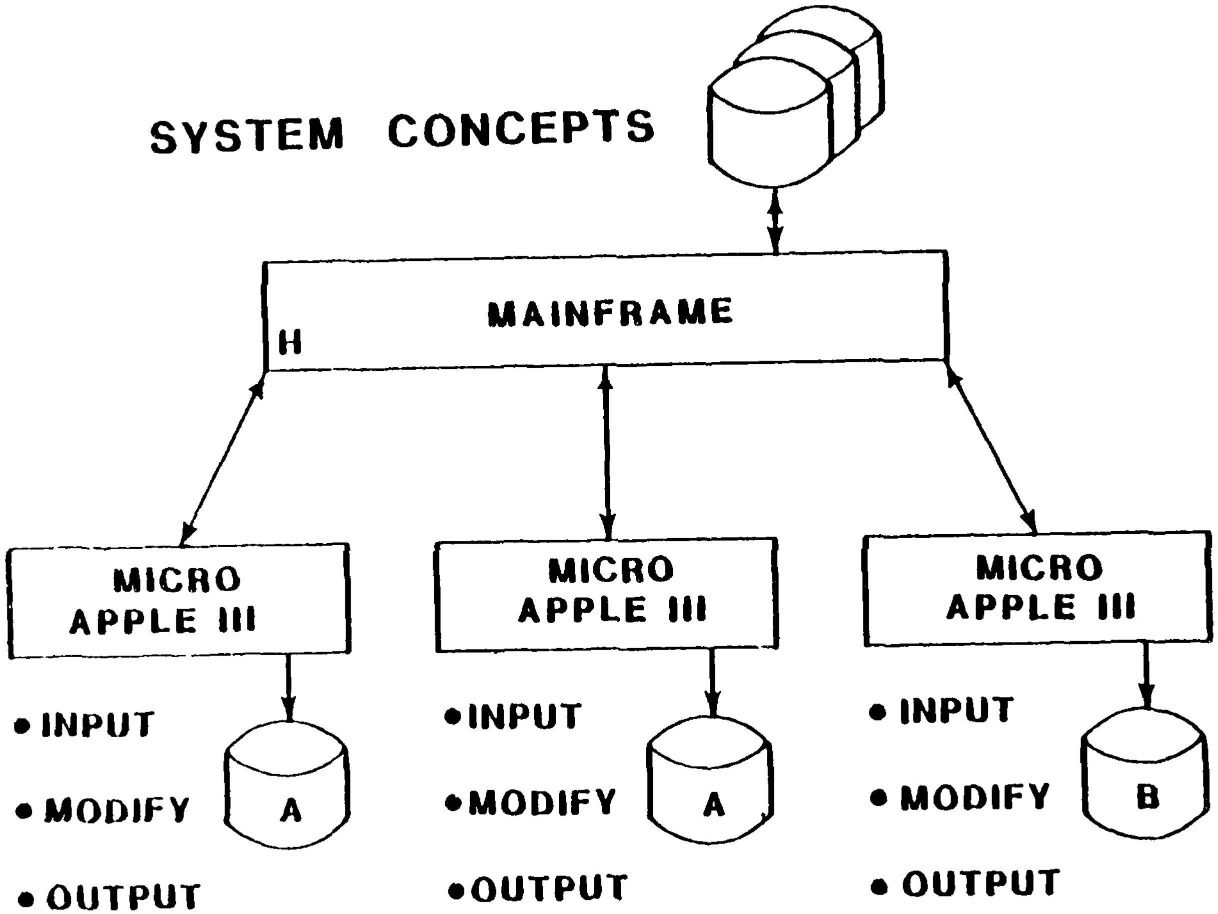

Figure 1-3. ETES Architecture.

guidance on all SDT commands and data elements. This "help" capability can be activated at any time during the operation of the SDT by pressing the escape key on the APPLE keyboard.

1.5.1.5 Generation of Data for SDT

In order to provide a capability for early training requirements estimation, the SDT will be used to describe system elements during the earliest phases of the acquisition process. To generate data during these early phases, comparability analysis procedures, which are part of the ETES Training Estimation Aids/Procedures, will be employed.

During the early phases of the system acquisition, when only information on a system's functional requirements is available, comparability analysis techniques will be used to identify existing subsystems which are similar to those of the new system. Historical data for these subsystems will then be collected and modified to (1) meet the differential characteristics of the new system and (2) correct any inherent deficiencies in the historical data base. By utilizing design and task data from comparable, existing systems, meaningful early estimates of training requirements can be made when only functional information on the projected system is available (see Figure 1-4). Later, as actual design concepts are developed, comparability analysis can be used to develop estimates of tasks and training program elements. Still later, when the actual system tasks are available, only the training program elements must be estimated.

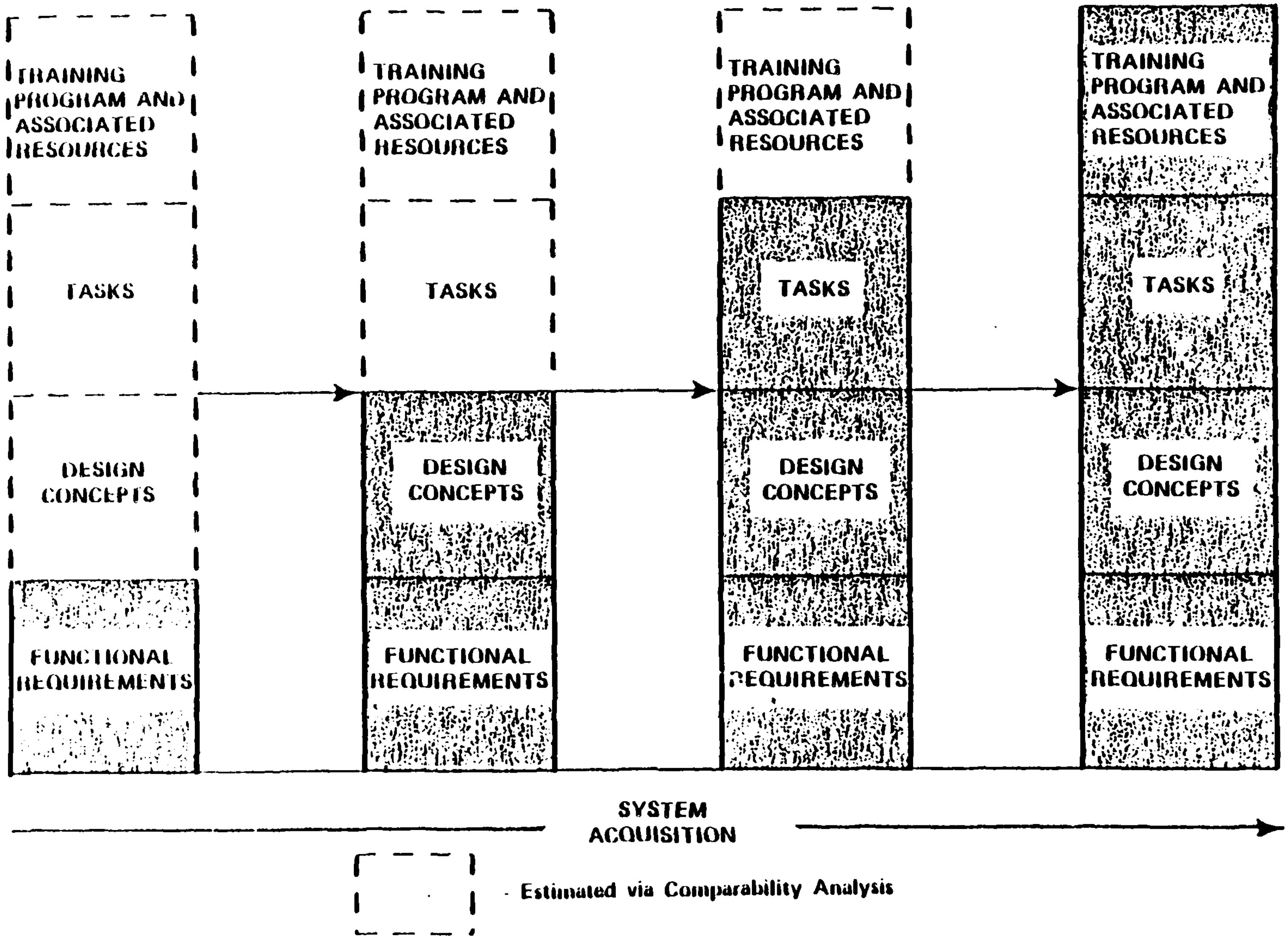

Figure 1-4. System Development Process for SDT.

Thus, by adding comparability analysis procedures to SDT data base management capabilities, the SDT will be capable of (1) describing alternative system concepts during the earliest phases of the acquisition process, (2) describing projected system elements, (3) relating alternative system concepts to a common framework so that meaningful comparisons can be made, and (4) refining system information as more accurate and more detailed data are developed.

1.5.1.6 Application of SDT in the System Acquisition Process

In its initial application to a particular weapon system development process, the SDT can be used to describe the system functional requirements which are generated during functional analysis. These requirements specify the functions which must be performed if the system is to satisfy its designated mission need. The SDT can be employed in a functional analysis as soon as the need for a particular system has been specified. Formally, this activity occurs after the approval of the requirements document at Milestone 0, which initiates the Conceptual phase of the acquisition process. However, the SDT could probably be used to describe functional requirements even prior to Milestone 0 if alternative system concepts were identified earlier.

Once the functional requirements for a system have been developed and described via the SDT, the SDT can be used to generate and describe system designs. These designs specify possible mechanisms for performing the desired functions. These mechanisms include equipment, personnel, and

Once developed, the system design(s) can also be described with the SDT.

Once the mechanisms for accomplishing the functions have been identified in the design concepts, the human tasks which must be performed to utilize the system designs can be specified. These tasks, which are the key building blocks of training development, can be documented in the SDT. Once the tasks are identified and specified in the SDT, training estimation aids and procedures can be used to determine training program elements, estimate training resources, and develop training products. The resulting training program and its associated resources can then be documented in the SDT.

The SDT, like the other components of ETES, is primarily designed for applications during the Concept Exploration phase of the acquisition process, which runs from Milestone 0 to Milestone 1. However, the SDT can also be used during subsequent phases of the acquisition process. The primary uses of the SDT applications during these later phases are to (1) make more detailed estimates of task and training resource requirements, (2) determine the impact of subsequent design changes on task and training requirements via the data base management capabilities of the SDT, and (3) conduct trade-off studies of proposed solutions to identified training problems.

1.5.2 Training Estimation Aids/Procedures (TEAP)

The Training Estimations Aids/Procedures are an integrated set of procedures and automated aids for performing six key

early training estimation functions: (1) Functional Requirements Analysis - Systematic description of the functions which the system must perform and, where necessary, estimation of the hardware/software design concepts needed to achieve these functions, (2) Task Generation - identification of the tasks required to operate or maintain the system, (3) Training Program Estimation - estimation of where and how the tasks should be trained, (4) Training Resource Estimation - estimation of the training resources needed to implement the training program, (5) Training Cost Estimation, and (6) Training Efficiency/ "Effectiveness" Estimation - estimation of the adequacy with which the training program can be expected to train personnel.

A listing of the ETES Training Estimation Aids and procedures is contained in Figure 1-5.

The TEAP includes new techniques as well as existing methodologies from other ARI research projects such as the Training Efficiency Estimation Model (Jorgensen, Kubala, and Atlas, 1981), recent work on cost and training effectiveness analysis by Dawdy, Chapman, and Frederickson (1981), and the Hardware Procurement - Military Manpower (HARDMAN) methodology (O'Brien, 1983; Mannle, 1981). These existing methodologies were modified to meet the specific requirements of early training estimation. Brief descriptions of the Training Estimation Aids and Procedures follow.

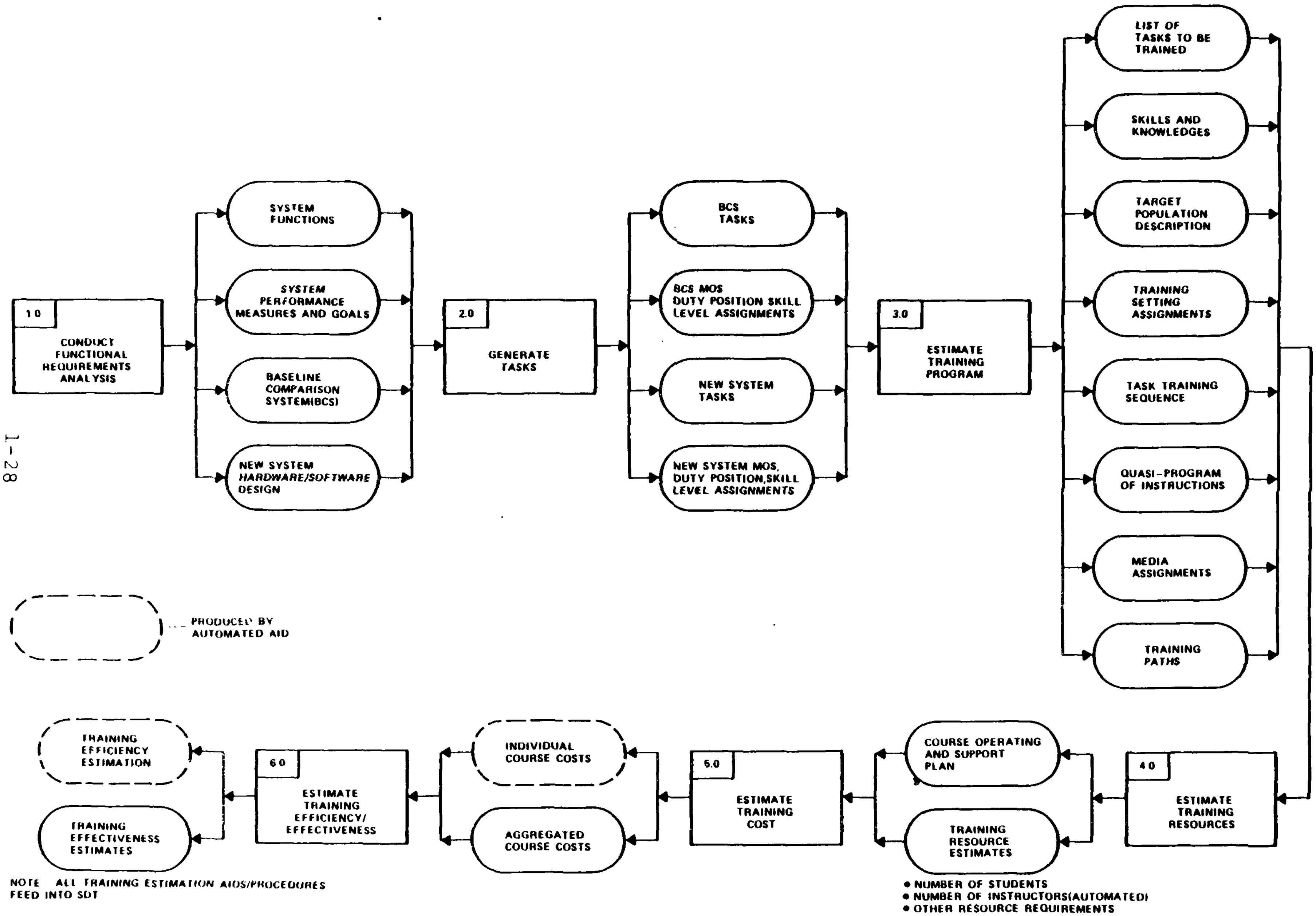

Figure I-5. ETES Training Estimation Aids/Procedures.

1.5.2.1 Functional Requirements Analysis

In order to estimate training requirements for a new system, the training developer must have information on the system's hardware/software design, and its functional requirements. Unfortunately, this information is often not available to training analysts during the early phases of the acquisition process. Consequently, it is often the case that no systematic estimates of training requirements are developed during these phases. The TEAP is designed to assist the training analyst in overcoming these problems by providing systematic techniques for estimating the system's functional requirements and hardware/software design during the early phases of system acquisition. The TEAP procedures for estimating system functions, and hardware/software design are at a general level. They are designed to provide the minimum amount of information needed for early training estimation. As the development of the system progresses, and actual information on system functional requirements and hardware/software design, are developed, these system elements no longer need to be estimated by ETES procedures but can be obtained directly from the combat developer (functional requirements) or materiel developer (hardware/software design and manpower requirements).

ETES functional requirements analysis procedures provide a description of the information which should be generated during the functional requirements analysis and the steps that one must go through to generate these elements.

Early estimates of system hardware/software design are generated via comparability analysis. Quite simply, comparability analysis involves (1) identifying comparable

existing systems, (2) collecting data on the comparable systems, and (3) modifying these data to reflect the differences between the comparable existing system(s) and the new system.

The most recent version of the DoD standard on Logistics Support Analysis (LSA) (MIL-STD-1388) identifies comparability analysis as the preferred method for estimating key system elements during the early phases of the acquisition process.

Identification of comparable equipment in ETES takes place in three major phases: (1) identification of the Predecessor equipment system(s), (2) identification of the Baseline Comparison System (BCS) equipment system, and (3) identification of the New equipment system.[2] The BCS system is constructed by (a) adding subsystems to the Predecessor subsystem to reflect additional capabilities required in the New system (i.e., the system under development), and (b) subtracting subsystems to reflect capabilities no longer required in the New system. The BCS provides a baseline for comparing the New system training requirements to other similar systems. The BCS concept is directly congruent with the new version of MIL-STD-1388 which specifically calls for the construction of a baseline comparison system during the early phases of the acquisition process.

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[2] The procedures described in this section were derived from the HARDMAN Methodology. A description of the HARDMAN Methodology is presented in Appendix D.

1.5.2.2 Task Generation Procedures

In the present version of ETES, comparability analysis is used as the principal means of estimating task requirements. In this approach, task data for the comparable existing system(s) are collected and modified to reflect the differences in design and/or employment between the New and comparable system.

The task generation process begins with the collection of task data for the equipments and MOSs in the BCS system. The BCS is composed of the existing subsystems (including the Predecessor subsystems) which come closest to meeting the New system functional requirements. The primary data source for existing task data is the Soldier's Manual since it, by definition, contains all tasks associated with an MOS. The task data from existing systems are updated to reflect any equipment or doctrinal changes that were made since the source was published.

Once the BCS task data has been collected and updated, this data is examined and compared to the New system hardware/software design and functional requirements. BCS tasks associated with equipments or functions which are no longer needed are eliminated. New tasks are added to reflect new equipment or functions. Descriptions of new tasks are developed in accordance with existing Instructional Systems Development (ISD) guidelines.

Identification of New system operator tasks is facilitated by examining the subsystem functions identified during the functional requirements analysis.

By adding and deleting BCS tasks, a New system task list can be constructed. The reason for each deletion/addition is documented using a systematic set of modification codes.

It is possible that a New subsystem may require the same task as a BCS subsystem but that the essential characteristics of this task must be changed to reflect the New system requirements. For example, the same task may be required for both the BCS and New system but the frequency with which the task is performed may differ.

To account for these changes to essential task characteristics, all tasks with major modifications are identified and the reason for each task modification is documented. Tasks associated with major changes to skills and knowledges are analyzed further to identify the specific skill and knowledge differences between the BCS and New system task. Tasks with minor changes in task elements are not examined further (It is assumed that their skills and knowledges have not changed). The reason for this strategy is that the purpose of ETES is to estimate training requirements rather than to develop training products (e.g., courses, manuals). Hence, only major changes to skills and knowledges which would significantly impact training requirements are determined.

Once tasks have been identified, their conditions and standards can be developed using existing ISD procedures. These same procedures are used to assess the adequacy of any new task descriptions which are generated during comparability analysis.

1.5.2.3 Training Program Estimation[3]

Algorithms are provided to assist the training analyst in determining the tasks to be trained and assigning these tasks to training settings. To provide input to these algorithms, tasks are rated on a series of task characteristics (e.g., frequency, learning difficulty). Several different algorithms are provided to meet the needs of different phases of the acquisition process.

Quasi-programs of instruction (QPOI) are constructed by (1) modifying or deleting modules from existing courses to reflect the task deletions and modifications made during task generation and (2) adding modules to reflect the unique requirements of the New system. As part of the QPOI construction process, the instructional methods and curriculum hours which must be devoted to each module are determined.

Media for the training program are selected by the application of an automated aid, the Media Selection and Efficiency Estimation Program. This program is an extension of the Training Efficiency Estimation Model (TEEM) produced by Jorgensen et al. (1981). The Media Selection and Efficiency Estimation Program significantly expands the capabilities of TEEM by recasting media selection as a dynamic programming problem and automating these procedures on the Apple III microcomputer. This automated program permits the user to employ the SDT to input and store the

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[3] The current version of ETES only contains procedures for estimating training programs for individual institutional training courses.

data needed to feed the media selection procedures. Using dynamic programming techniques, the program can assign tasks to media in a manner that optimizes efficiency, relative cost, or efficiency and relative cost.

Efficiency is determined by comparing the stimulus, response, and feedback characteristics of the individual task to the stimulus, response, and feedback characteristics of potential media categories. More specifically, a score is calculated which describes the match between media and task characteristics. Efficiency for each task-media combination is calculated by dividing this score by the maximum match that may be achieved for the task.

Total efficiency for a set of tasks is determined by aggregating the efficiency score for individual tasks. An additional efficiency measure can be calculated by weighting the efficiency of each task by the task criticality score. This task criticality score is calculated by aggregating the task factors typically used in selecting tasks for training (e.g., task frequency, percent members performing, task delay tolerance, etc.).

1.5.2.4 Estimation of Training Resources

These procedures estimate the training resources needed to implement the training program. The training resources encompassed by these procedures include (a) the number of students to be trained, (b) number of instructors and support personnel, (c) facilities requirements, (d) training device and training equipment requirements, and (e) ammunition requirements. Included among the procedures are

techniques for using off-the-shelf automated worksheet software (e.g., VisiCalc) for storing and applying several of the resource determination algorithms.

1.5.2.5 Estimation of Training Costs

These procedures estimate the costs of the resource requirements and aggregate these costs into a total course cost. The procedures include techniques for using off-the-shelf automated worksheet software to calculate course costs. The procedures also describe how to use modified data from comparable existing courses to assist in the cost estimation process.

1.5.2.6 Training Efficiency/Effectiveness Estimation

Procedures are provided for determining the training efficiency of selected aspects of the training program (e.g., media). Training efficiency is defined as a measure of the extent to which the characteristics of the training program element match the task characteristics of the New system. For example, media training efficiency is determined by comparing the stimulus, response, and feedback characteristics of the tasks to the stimulus, response, and feedback characteristics of potential media categories. An additional variant of this efficiency measure may be obtained by weighting each task by its "criticality" where criticality is determined by aggregating weighted scores of key task characteristics (e.g., frequency, consequences of inadequate performance).

Training "effectiveness" is determined by using modified versions of procedures outlined in Dawdy, et al (1981). More specifically, a group of subject matter experts is presented with the following information for each task: (a) the target population description of the personnel who will perform the task, (b) a description of the task including its associated conditions, job performance standards, and general skills and knowledges, (c) a description of the training program or training program elements (e.g., course length, methods, media) that will be used to train the task, and (d) the criterion which must be achieved for the task (if different from the job performance measure). Each subject matter expert is then asked to estimate the expected percentage of soldiers in the target population who will pass the criterion given that training program.[4]

It should be noted that the ETES TEAP is designed to estimate training requirements for a New system. The TEAP is not designed to provide techniques for actually developing instructional materials or programs (e.g., course, instructor packages, student packages, training literature, training devices). Thus, the TEAP will assist training analysts in determining what instructional materials/programs should be produced, what the content of these materials/ programs should be, and in estimating the cost of these materials/programs.

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4 It is recognized that this measure of effectiveness, may differ from other conceptualizations of training effectiveness. It is also recognized that this approach only provides a gross measure of "effectiveness" that should only be used during the earliest phases of the acquisition process.

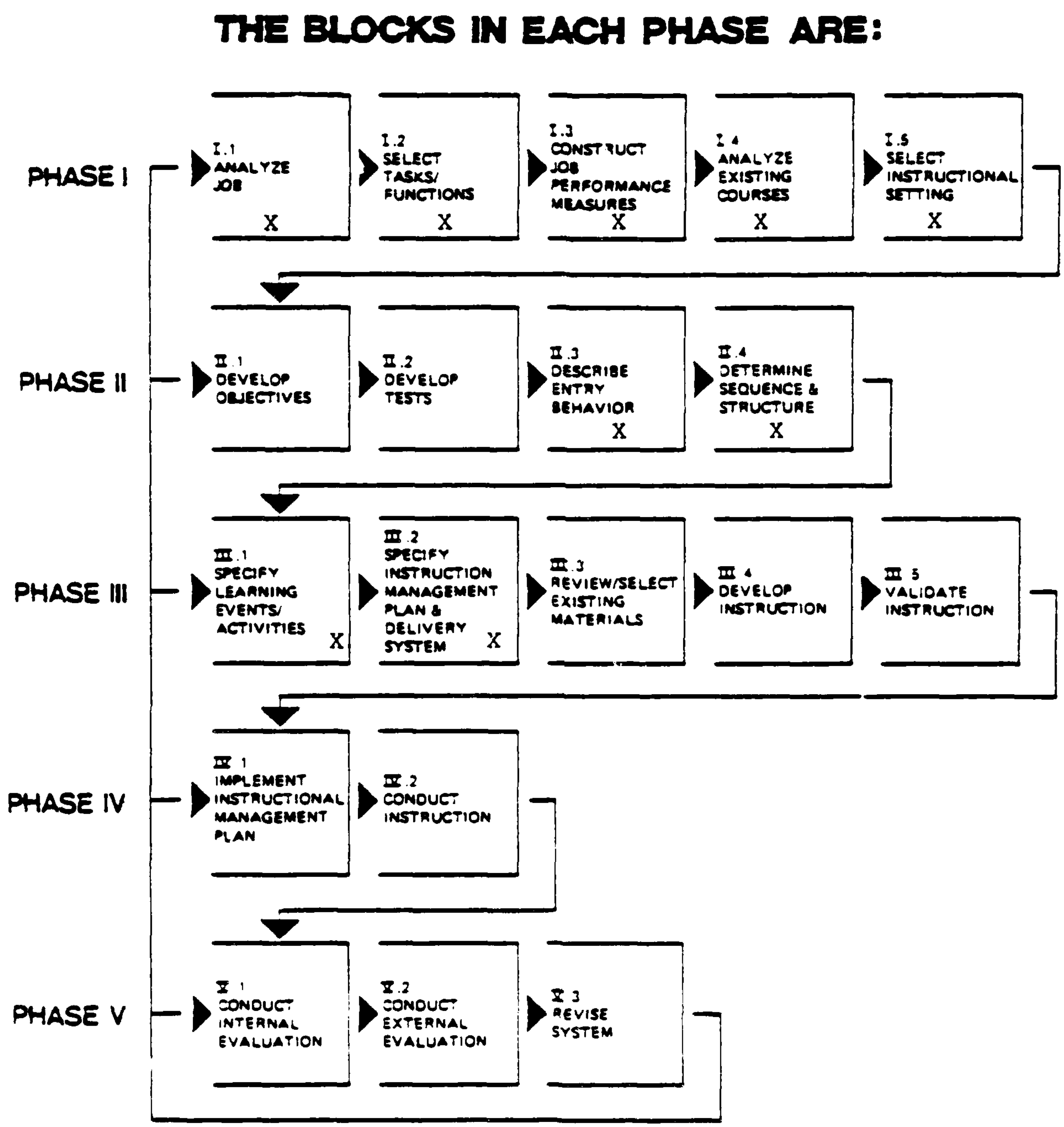
This focus on training requirements estimation rather than on training product development is one of the unique characteristics of the TEAP. This focus on training requirements distinguishes it from other existing training development methodologies such as the Army's Instructional Systems Development (ISD) process and the Army Research Institute's Training Developer's Decision Aid (Hawley, 1979).

The training requirements produced by the TEAP provide front-end information needed for the early planning and analysis of training programs. The training requirements information produced by the TEAP provides the foundation for the actual construction of training products in ISD and other related methodologies. Techniques and methodologies which can be used to develop training products are provided in TRADOC Pam 350-30, Schulz and Farrell (1980), Hawley (1979), and Fink (1981). An overview of the relationship between ISD and ETES is provided in Figure 1-6.

1.5.3 Evaluative Technology

The Evaluative Technology is an integrated set of procedures and automated tools for (1) developing figures-of-merit for assessing the integrated impacts of the training requirements developed in the Training Estimation Aids/Procedures, (2) identifying potential problem areas for system training and the likely sources of these problems, (3) identifying/evaluating training problems, (4) developing training-related input to key acquisition documents, and (5) determining/evaluating training development schedules (see

ISD BLOCKS IN EACH OF THE FIVE ISD PHASES



X = Function Covered by ETES

FIGURE 1-6. RELATIONSHIP BETWEEN ISD AND ETES

Figure 1-7). A summary of the procedures in each of these areas is provided below.

1.5.3.1 Development of Figures-of-Merit

Procedures are included for identifying figures-of-merit which summarize the essential features of the training requirements. Eight potential training figures-of-merit are utilized including (1) cost, (2) training efficiency, (3) training "effectiveness", (4) congruence with training development guidelines, (5) congruence with program requirements, (6) training complexity, (7) training capacity, and (8) feasibility. In addition, a procedure is provided for constructing a summary evaluation score which aggregates the scores on the individual figures-of-merit. This summary evaluation score provides a global measure of the "goodness" of a training program.

1.5.3.2 Identification of Problem Areas

Procedures are included for identifying training problem areas. These problem areas consist of the Army Military Occupational Specialties (MOSs) which have high figure-of-merit scores relative to (1) the Predecessor system, and/or (2) the other MOSs in the New system. Procedures are also provided for identifying the courses, equipments, and tasks which contribute to the high figures-of-merit and identifying the training program elements which are likely causes of the high figure-of-merit scores.

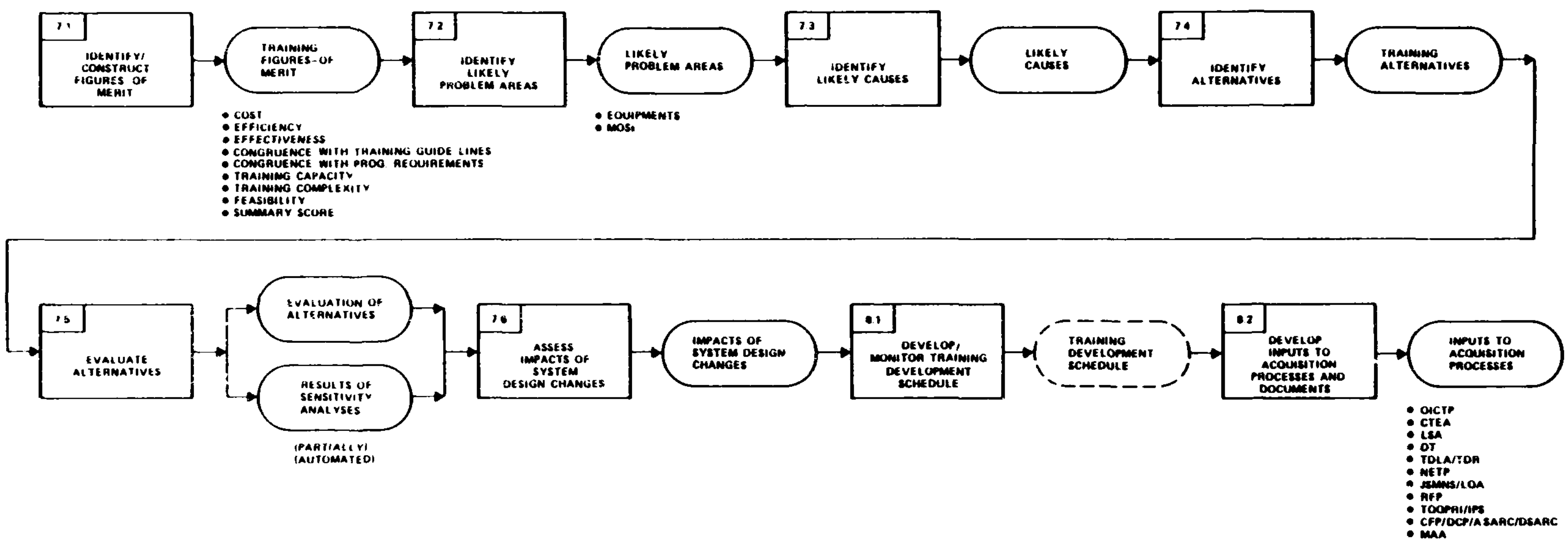


Figure I-7 ETES Evaluative Technology

1.5.3.3 Identification and Evaluation of Alternatives

Guidelines are included for (1) identifying training alternatives which can address the training problems, (2) evaluating the training alternatives through selected reapplication of TEAP and Evaluative Technology procedures, (3) conducting sensitivity analyses of key parameters, and (4) assessing the impact of non-training system changes (e.g., hardware/software changes) on training.

1.5.3.4 Development and Evaluation of Training Schedules/Plans

Construction of training development schedules for emerging systems is a difficult process. Over 100 developmental events are listed in TRADOC Reg 351-9, the Army regulation governing training plan development. The sequential relationships among these events are complex and are not described in any systematic and integrated manner in TRADOC Reg 351-9. To assist users in developing training schedules, procedures are provided for using automated, off-the-shelf scheduling software (e.g., VisiSchedule) to track and monitor the training development schedule. By using this software, the training developer can quickly and efficiently respond to changes in the training development schedule. Use of off-the-shelf scheduling software is facilitated by the inclusion of an input data diskette which (a) describes the events in the training development process (as specified in TRADOC Reg 351-9), (2) describes the temporal/sequential relationships among these events and key acquisition milestones, and (3) lists the expected duration of these events for a "typical" major Army weapons system. This data diskette significantly reduces data input requirements. In addition, it eliminates the need for an

analysis of the complex sequential relationships among training development events which are either implicitly or explicitly specified in TRADOC 351-9.

1.5.3.5 Develop Inputs to Acquisition Processes and Documents

Major Army acquisition processes and documents related to early training estimation were identified and are summarized in Table 1-4.

1.6 RELATIONSHIP BETWEEN ETES AND OTHER ARI PROJECTS

ETES is part of the Army Research Institute's thrust to develop systematic techniques for determining manpower, personnel, and training requirements for developing Army systems. Other major projects currently in this thrust include the Man-Integrated Systems Technology (MIST), the Army Manpower and Personnel Requirements Estimation Program (ARMPREP), the Army Hardware Procurement-Military Manpower (HARDMAN) program, and the Human Resources Test and Evaluation System (HRTES). MIST is the central project in this thrust since it will integrate the other projects in the thrust. Table 1-5 summarizes the data that each component will contribute to the three phases of MIST development. ETES will provide MIST with two critical components: (1) techniques for estimating and evaluating training requirements and (2) a prototype data base management system (the SDT) for storing MPT information.

A description of the other projects in the ARI thrust is provided in Appendix D.

Table 1-4 Major Army Acquisition Processes and Documents Related to Early Training Estimation

- Cost and Training Effectiveness Analysis (CTEA)
- Outline Individual and Collective Training Plan (OICTP/ICTP)
- Logistics Support Analysis (LSA)
- Operational Testing (OT)
- Training Device Requirements, Documents, and Processes
  - Training Device Letter of Agreement (TDLOA)
  - Training Device Requirements (TDR)
  - Training Device Letter Requirement (TDRL)
  - Training Device Study (TDS)
- New Equipment Training
- System Requirements/Documents
  - Justification for Major System New Start (JMSNS)
  - Letter of Agreement (LOA)
- Request for Proposal (RFP) Development/Evaluation
- Personnel Documents/Processes
  - Tentative Quantitative and Qualitative Personnel Requirements Information (TQQPRI)
  - Integrated Personnel Summary (IPS)
- System Level Documents/Processes
  - Concept Formulation Package (CFP)
  - Cost and Operational Effectiveness Analyses (COEA)
  - Tradeoff Determination (TOD)
  - Best Technical Approach (BTA)
  - Decision Coordinating Paper (DCP)
  - Defense System Acquisition Review Council (DSARC)
  - Army System Acquisition Review Council (ASARC)
- Mission Area Analysis

Table 1-5 RELATIONSHIPS BETWEEN PROJECTS IN ARI THRUST

FUNCTION	MIST TESTBED	MIST EXTENSION	MIST REFINEMENT
• Conduct Functional Reqs. Analysis	-	-	-
- Identify Functions & Goals	ETES	ETES	ETES
- Identify Baseline Comparison System	HARDMAN	HARDMAN	HARDMAN
- Identify New System Design Hardware/Software Design Concept	HARDMAN	HARDMAN	HARDMAN
• Generate Tasks	ETES	ETES	ETES-II
• Conduct Training Reqs. Analysis	-		
- Estimate Training Program	ETES	ETES	ETES-II
- Estimate Training Resources	ETES	ETES	ETES-II
- Estimate Training Costs	ETES	ETES	ETES-II
- Evaluate Training Program	ETES	ETES	ETES-II
• Conduct Manpower Reqs. Analysis	-	-	-
- Assign Tasks to MOS, Duty Position and Skill Level	ETES, HARDMAN	ETES, HARDMAN, ARMPREP	ETES, HARDMAN, ARMPREP
- Determine Workload	HARDMAN	HARDMAN, ARMPREP	HARDMAN, ARMPREP
- Determine Quantitative Manpower Reqs.	HARDMAN	HARDMAN, ARMPREP	HARDMAN, ARMPREP
- Determine Manpower Costs	HARDMAN	HARDMAN	HARDMAN
- Evaluate Manpower Reqs.	HARDMAN	HARDMAN, ARMPREP	HARDMAN, ARMPREP
• Conduct Personnel Reqs. Analysis	-	-	-
- Identify Personnel Demand	HARDMAN	HARDMAN	HARDMAN
- Identify Personnel Supply	NC	NC	NC
- Compare Supply with Demand	NC	NC	NC
- Evaluate Personnel Reqs.	HARDMAN	HARDMAN	HARDMAN
• Conduct Human Factors Reqs. Analysis	-	-	-
- Assess Operator Manning Reqs.	NC	NC	NC
- Assess System Reliability	NC	NC	NC
- Assess System Maintainability	HARDMAN	HARDMAN	HARDMAN
- Assess System Habitability	NC	NC	NC
- Evaluate Overall HF Impacts	NC	NC	NC

Table 1-5 (Continued..)

FUNCTION	MIST TESTBED	MIST EXTENSION	MIST REFINEMENT
• Assess Integrated Impacts of MPT and Human Factors	HARDMAN	HARDMAN	HARDMAN, ETES-II
• Assess Impact of MPT/HF on Total System	NC	NC	NC
• Provide MPT/HF Interface with OT Testing	NC	HRTES	HRTES
• Management Functions	-	-	-
- Data Base Management	ETES (SDT Provides Prototype System)	ETES, MIST,	ETES, MIST, ETES-II
- Management Information and Communication	NC	MIST (Initial Capability)	MIST (Additional Capability)
- Input to Acquisition Processes and Documents	ETES (Training) MIST (QQPRI and BOIP)	ARMPREP (QQPRI and BOIP), HRTES (OT Testing), MIST	ETES, MIST, ARMPREP. HRTES

MIST - Man Integrated System Technology Project
ETES - Early Training Estimation System (Initial Development Study)
ETES II - Second ETES Development Study
ARMPREP - Army Manpower and Personnel Requirements Process Study
HRTES - Human Resource Test and Evaluation System Study
HARDMAN - Army Hardware versus Manpower Procurement Studies
NC - Not Covered in MIST

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SECTION 2 - TASK 1: ASSESS EXISTING CONCEPT DEVELOPMENT PROCEDURES

During this task, three major activities were accomplished. First, Army Life Cycle System Management Model processes and documents were examined to identify the products that must be developed by an early training estimation system and to identify the likely users of these products. Second, interviews were conducted with likely users of the SDT to more precisely define current early training estimation practices and needs. Third, the psychological aspects of the design process were examined to identify problem solving aids which might be included in any automated aids developed in ETES.

2.1 ASSESS LCSMM INTERFACES

During this task, a detailed review was conducted of existing Army and DoD documents relating to system acquisition or training development. The purpose of this review was to (1) identify current requirements for early training estimation, (2) identify likely data elements for inclusion in the SDT, and (3) identify any tools currently being used for early training estimation. The review focused on documents and processes related to Mission Area Analyses (Pre-Milestone 0), Concept Exploration, and Demonstration and Validation phases of the acquisition process. The ETES review of training-related acquisition processes was the major input for a later report describing manpower, personnel and training interfaces in the Army

LCSMM produced by Wagner (1982) as part of the Man-Integrated Systems Technology (MIST) project.

Table 2-1 describes the documents and processes which were identified as having the most relevance to early training estimation.

The two documents/processes which were determined to be the most critical to early training estimation were (1) the Outline Individual and Collective Training Plan (OICTP) and (2) Cost and Training Effectiveness Analysis (CTEA).

2.1.1 OICTP/ICTP

The OICTP and ICTP are plans which support the development and implementation of new or revised individual and collective training programs at institutional and unit levels. The OICTP and ICTP are the major resource and planning documents for developing training for new Army systems. An approved OICTP is sufficient justification to enter manpower and funding requirements into the Army's programming and budgeting processes for inclusion of the TRADOC Review of Manpower (TRM). As specified in existing regulations (TRADOC Reg 351-9), the OICTP/ICTP contains a proposed training concept and training strategy. The concept and strategy are typically generated by the proponent school responsible for the New system's training requirements.

The OICTP/ICTP is generally an evolving document that increases in specificity (via appropriate updates) as the

Table 2-1 LCSMM DOCUMENTS AND PROCESSES RELATED TO EARLY TRAINING ESTIMATION

DOCUMENTS/PROCESS	IMPLICATIONS FOR EARLY TRAINING ESTIMATION
Outline Individual and Collective Training Plan (OICTP/ICTP) (see TRADOC Reg 351-9)	The OICTP/ICTP is the Major Resource and Planning Document for Training. It Contains Summary and Schedule Information on all Major Training Product Areas.
Cost and Training Effectiveness Analysis (CTEA) (see TRADOC Training Effectiveness Analysis Handbook, TRADOC Reg 350-4)	The CTEA is Potentially the Most Critical Document Related to Early Training Estimation. A CTEA Requires Users to Identify and Evaluate Training Alternatives. Currently, However, CTEAs are Seldom, if ever, Conducted Prior to Milestone I.
Logistic Support Analysis (LSA) (see AR 700-127, DARCOM-P-750-16, MIL-STD-1388)	Process for Identifying Integrated Logistics Support (ILS) Elements. Training is one of these Elements. Currently, however, LSA is Seldom if ever, Conducted Prior to Milestone I.
Operational Testing (OT) (see AR 1000-1, AR 700-126, AR 702-9, AR 70-1, AR 70-10 and AR 71-3)	A Comprehensive Early Training Estimation System could Assist in the Identification of Training-Related Test Issues for Operational Testing (OT-1).
Training Device Letter of Agreement (TDLOA)/ Training Device Requirement (TDR) (see TRADOC Cir 70-10, Training Device Requirements Guide)	The TDLOA and TDR are Requirements Documents which Initiate the Development of New Training Devices. ETES Facilitates Early Initiation of these Documents.
New Equipment Training Plan (NETP) (see AR 350-35)	The NETP is the Primary Planning Document for New Equipment Training, the Interim Training Required to Introduce the New System into the Army Inventory. ETES Facilitates the Development of a More Accurate and Earlier NETP.
Justification for Major New System Start (JSMNS) and Letter of Agreement (LOA) (see DoD 5000.2, and AR 71-9)	The JSMNS and LOA are the Primary Requirements Documents for New Systems. These Documents often Contain General Statements of the System Training Requirements or Training Concept. ETES Facilitates Development of this Information.

Table 2-1 (Continued..)

DOCUMENTS/PROCESS	IMPLICATIONS FOR EARLY TRAINING ESTIMATION
Tentative Quantitative and Qualitative Personnel Requirements Information (TQQPRI) and Integrated Personnel Summary (IPS) (see AR 71-2 and TRADOC Reg 600-4)	The TQQPRI and IPS are Key Documents in Describing Personnel Requirements for the New System. ETES Supplies Task and Skill Information which Facilitates the Identification of MOS and Skill Levels which are Critical Parts of these Documents.
Request for Proposal (RFP)/Proposal Evaluation	ETES Provides Input for the Identification of Training Requirements for Inclusion in the Weapon System RFP and Could Provide a Baseline from Which to Evaluate Contractor Responses to the RFP.
Tradeoff Determination (TOD), Bets Technical Approach (BTA), Concept Formulation Package (CFP), Decision Coordinating Paper (DCP), Defense System Acquisition Review Council (DSARC), Army System Acquisition Review Council (ASARC). (see AR 71-9, AR 70-27, AR 1000-1, AR 15-14, and TRADOC Reg 11-8)	The TOD, BTA, CFP, DCP, DSARC Review and ASARC Review are all High Level Documents Concerned with Overall System Evaluation. Training Related Input ot these Documents are Provided through the Training Planning Process (OICTP/ICTP/NETP), CTEA Analysis and LSA Analysis.
Mission Area Analysis (MAA) (see TRADOC Handbook on Mission Area Analysis)	Mission Area Analysis is the Ongoing Evaluation of Current Capabilities in a Functional Area. MAA occurs Prior to Milestone 0. ETES Provides a Capability for Evaluating the Training-Related Implication of the Alternatives which are Generated During MAA.

system under development is further defined. The OICTP/ICTP provides significant feeder data for the Tentative Qualitative and Quantitative Personnel Requirements Information (TQQPRI), the Training Effectiveness Analysis (TEA), and the New Equipment Training Plan (NETP). After LOA approval, the OICTP can be used by the contractor to facilitate the identification of training requirements conducted as part of the logistic support analysis.

The OICTP/ICTP is intended to guide the development of training subsystem requirements and to provide the general framework for their future incorporation into the existing training base. The regulations specifically emphasize the intention to use the proposed training concept in the OICTP/ICTP to "... identify the constraints which training requirements and resources may impose on the design of the material system" (TRADOC Reg 351-9, pg. 5). The regulation also mandates use of the OICTP/ICTP as the vehicle to describe "...the integration of the training subsystem into the development of the total system and the integration of the developing system into ongoing training systems."

TRADOC Reg 351-9 further stipulates that the OICTP/ICTP must incorporate the principles of Army Training 1990 (AT 90) into training for a new system, for both institutional and unit training and at all skill levels for the MOS/SC affected. The OICTP/ICTP is intended to develop and describe a systematic and feasible strategy for training, extending from the development of "initial qualification" to continuing "sustainment of the proficiencies" needed for the successful fielding and operational deployment of the system being acquired.

As specified in existing regulations, the OICTP/ICTP provides information on the training required to integrate replacements from the training base into the unit, and to qualify personnel for higher level tasks as they advance in grade. The OICTP/ICTP is further directed to provide information on the identification, quantification, and need for training devices, simulators, documentation/ publications, training aids, support facilities, instructors, costs, and all other support and logistic considerations necessary for the implementation and test of the proposed training plan.

Table 2-2 provides an overview of the elements in and OICTP/ICTP and describes which ETES procedures can provide input to the development of these elements.

2.1.2 The Cost and Training Effectiveness Analysis (CTEA)

The CTEA process is potentially the most critical LCSMM process related to early training estimation since it requires the user to not only estimate what the training program will look like (as does the OICTP/ICTP), but also to evaluate these training programs and to provide training related input into the overall system development and evaluation process.

The new TRADOC Reg 351-9, governing the OICTP process, contains the most current definition of the CTEA. It defines CTEA as "a methodology which involves documented investigation of the comparative effectiveness and costs of alternative training systems for attaining defined performance objectives." The definition further specifies

Table 2-2. Relationship Between OCITP and ETES Functions.

ELEMENTS IN OICTP[1]	RELATED ETES PROCEDURES/AIDS: PROCEDURE/AID	RELATED ETES PROCEDURES/AIDS: RELATIONSHIP
• System Description	1.0 Conduct Functional Reqs Analysis	ETES provides procedures for estimating system functional and system hardware/software design concepts during earliest phases of the acquisition process.
• System Milestones	8.1 Develop/Monitor Training Development Schedule	ETES automated planning and scheduling technique (APST) lists major system milestones related to training development.
• Training Development Schedule	8.1 Develop/Monitor Training Development Schedule	ETES automated planning and scheduling technique (APST) provides automated tool for describing and updating training development schedule.
• Descriptions of Training Products	-	-
- SPA/TM	NC	-
- SM/TG	NC	-
- SQT	NC	-
- ARTEP	NC	-
- Resident Training Program	3.0 Estimate Training Program	ETES contains procedures for estimating training program during earliest phases of WSAP
- Resident Training Equipment	4.5 Determine Training Device and Equipment Reqs.	ETES contains general guidelines for estimating requirements.
- Training Devices	4.5 Determine Training Device and Equipment Reqs.	ETES contains general guidelines for estimating requirements.
- Training Literature	NC	-
- TEC	NC	-
- Audiovisual	NC	-
- ACCP	NC	-
- Facilities/Ranges	4.4 Determine Facilities Reqs.	ETES contains general guidelines for estimating requirements.
- Ammunition	4.6 Determine Reqs. for other training resources	ETES contains general guidelines for estimating requirements.

[1] Source - TRADOC Req. 351-9
NC- Not Covered in ETES

Table 2-2 (continued)

ELEMENTS IN OICTP	RELATED ETES PROCEDURES/AIDS		
		PROCEDURE/AID	RELATIONSHIP
- Net	8.2	Develop Inputs to Acquisition Process	ETES contain general procedures for modifying early training program concepts for use in new equipment training.
• Training Resources	4.0	Estimate Training Resources	ETES contains procedures for developing early estimates of resource requirements for resident training courses.

that a CTEA can focus on any one or a combination of the following:

- o Training concepts
- o Training strategies
- o Training equipment/devices
- o Programs of instruction
- o Training impacts of
  - New materiel
  - Organization
  - Tactics
  - Families of systems

Regardless of the specific focus of the CTEA, TRADOC Regulation 351-9 stipulates that the CTEA should include an analysis of the attainable levels of proficiency and the costs associated with each alternative. In addition, a CTEA should include a cost effectiveness trade-off analysis of the feasible alternatives. This regulation further specifies that a CTEA must:

- o Ensure that training development is initiated early in the life cycle of hardware systems and is accomplished in coordination with combat developments,
- o Optimize soldier-hardware subsystem interface,
- o Ensure that all feasible training subsystem alternatives are considered,
- o Optimize soldier-training subsystem interface,

- Optimize soldier-training subsystem interface,

- Recommend the preferred training alternative based on cost and training effectiveness, and

- Provide decision makers with more precise information at critical points in the acquisition process concerning the total system (comprising the training, hardware, and other subsystems).

These objectives demonstrate that the CTEA, unlike the OICTP and the QQPRI/BOIP, is an early training-related document intended, in theory at least, to influence the hardware system design. This is a very significant difference from the OICTP which is, by regulation, primarily an MPT planning and resource document. The steps in the CTEA process and the corresponding ETES procedures are detailed in Table 2-3.

2.1.3 Identification of LCSMM Reports

As part of the review of existing LCSMM processes, an attempt was made to identify any report formats which might be relevant to early training estimation, and in particular, to the identification of data elements for the SDT. Table 2-4 summarizes the report formats that were identified during this process. A listing of the documents that were reviewed during this process is contained in Appendix E.

Table 2-3. Relationship Between CTEA and ETES Functions

STEPS IN THE CTEA PROCESS[1]	RELATED ETES PROCEDURES/AIDS: PROCEDURES/AIDS	RELATED ETES PROCEDURES/AIDS: RELATIONSHIP
• Analyze Hardware	1.0 Conduct Functional Requirements Analysis	These ETES procedures can be used to estimate system functional requirements and system hardware/software design concepts during earliest phases of the acquisition process.
• Determine Tasks to Operate Hardware	2.0 Generate Tasks	These procedures can be used to generate tasks during the earliest phases of the acquisition process.
• Develop Soldier Profile	3.3 Identify Target Population	ETES provides procedures for estimating tasks and skills. With this data as input, target population descriptions can be operated through existing procedures in the job and task analysis handbook.
• Determine Soldier Capabilities	NC	-
• Analyze Soldier-Hardware Subsystem Interface	7.2 Identify Problem Areas	ETES provides general guidelines for identifying equipments associated wi .. negative training impacts (relative to baseline system)
• Design Alternative Training Subsystems	3.0 Estimate Training Program 7.4 Identify Alternatives	ETES provides procedures for generating an early training concept and general guidelines for identifying training alternatives. Current ETES only deals with institutional training.
• Estimate Cost	5.0 Determine Training Cost	ETES provides procedures for estimating training costs for institutional training courses
• Estimate Effectiveness	6.0 Estimate Training Efficiency/Effectiveness	ETES provides procedures for estimating training efficiency and for developing a crude measure of training effectiveness that can be used early in the WSAP.
• Update CTEA Based on DT/OT Results	NC	-
• Participate in DT/OT I Testing Cycle	8.2 Develop Inputs to Acquisition Processes and Documents	ETES provides critical input data to HRTES which can be used to develop test issues for OT
• Select Best Conceptual Training Alternatives for Further Development	7.5 Evaluate Alternatives	ETES provides procedures for evaluating early training concepts and alternatives.
• Modify Training Alternatives Based on Hardware System Development	7.6 Assess Impact of System Changes	ETES provides general procedures for rerunning the training estimation process in response to system changes
• Prepare More Detailed Cost Effectiveness Estimate	NC	-
• Develop Training Concept (Institutional Training Course) 1	-	-

1 Source, TEA Handbook

NC = Not Covered in ETES

Table 2-3 (continued)

STEPS IN THE CTEA PROCESS[1]	RELATED ETES PROCEDURES/AIDS: PROCEDURES/AIDS	RELATIONSHIP
- Courses Impacted	3.6 Construct Quasi-POI	Covered fully in ETES procedure
- Course Description	3.6 Construct Quasi-POI	Covered fully in ETES procedure
- Changes to Current Courses	3.6 Construct Quasi-POI	Covered fully in ETES procedure
- Student Load per Year	4.2 Determine No. of Students to be Trained	Covered fully in ETES procedure
- Average Grade per Student	NC	-
- Student Source	3.3 Identify Target Population Description	Covered fully in ETES procedure
- Class Frequency	4.1 Construct Operating and Support plan	Covered fully in ETES procedure
- Class Length	3.6 Construct Quasi-POI	Covered fully in ETES procedure
- Start Year	4.1 Construct Quasi-POI	Covered fully in ETES procedure
- Instructor Requirements	4.3 Identify Instructor Requirements	Covered fully in ETES procedure
- Support Personnel Requirements	4.3 Identify Support Personnel Requirements	ETES procedure provides general guidelines and algorithms for Determining Requirements
- Expended Equipment Per Class	4.6 Estimate Other Resources	ETES procedure provides general guidelines and algorithms for Determining Requirements
- Non-expended Equipment Per Class	4.5 Determine Training Device and Train Equip. Requirements	ETES procedure provides general guidelines and algorithms for Determining Requirements
- Exportable Training	NC	-
- Exportable Software	NC	-
- Training Teams	NC	-
- Exportable Hardware	NC	-
- Facility Requirements	4.4 Determine Facilities Reqs.	ETES procedure provides general guidelines and algorithms for determining requirements.
• Prepare/Submit Reports	NC	-

[1] Source, TEA Handbook

Table 2-4 Summary of Standardized Reports Related To Early Training Estimation

Title	Document	Items
Task List, Training Setting Assignments	TRADOC CIR 351-8	Task Number, Task Description, Training Materials, Responsibility for Training
MOS Training Program Worksheet	TRADOC CIR 350-3	Task No., Task Description, No. of Duty Positions, Training Products, Supporting Tasks
ICH Computation Sheet	TRADOC CIR 351-12	Course Module, Instructional Hours, Method, Instructor Contact Hours
Task Analysis For Manning Report	DI-H-0006 (MIL-STD-XYZ) DI-H-0004	Equipment Nomenclature Part Number, Task No., Task Description
Task Inventory Report	DI-H-0001	Mission, Scenario, Conditions, Function, Job/Duty Position

Table 2-4 (continued)

Title	Document	Items
Task List	MIL-M-63040(TM)	JPG/ETM, Equipment, MOS, Item Code, Tasks/Subtasks, Conditions, Standards, Comments
Task Selection Sheet	TRADOC PAM 351-4(T)	Task No; Task Description Task Characteristics/ Factors
Job and Task Analysis (Worksheet)	TRADOC PAM 351-4(T) TRADOC REG 351-4	Task No., Task Description; Condition, Standard, Job Title, Supervisory Job Reqs., Task Characteristics, Enabling Skills and Knowledge, Equipment Used to Perform Task.
Task Analysis Worksheet	ARI Research Product 80-13*	MOS Skill Level, Task Number, Task, Initiating Cues, Conditions, Standards, Reference/Tips
Task Summary Sheet	ARI Research Product 80-13	Task, Conditions, Standards, References, Performance Description
Task Information Sheet	TRADOC CIR 351-12	Task Number, Title, Standard
Course Summary	TRADOC CIR 351-12	Course, Hours

Table 2-4 (continued)

Title	Document	Items
Task Cluster Annex	TRADOC CIR 351-12	Task Cluster, Hours, Student/Instructor Ratio, Lesson Objective, Lesson Reference
Training Resource Section	TRADOC CIR 351-12	Course Number, Title, Manpower Requirements, Expense Elements
MOS Course Costs	TRADOC Cost Analysis Program	Course Costs by Courses in MOS
Course Costs	ATRM-159	Course Title, Course Number, MOS, Course Cost Elements
Equipment List	MIL-M-63035(TM)	FSN, Part Number, FSCM, Description
Tool and Test Equipment	MIL-M-63035(TM)	Maintenance Level, Nomenclature, National Stock Number
Maintenance Allocation (Chart)	MIL-M-63035(TM)	Group Number, Component, Maintenance Function, Maintenance Level, Tools and Test Equipment No.

Table 2-4 (continued)

Title	Document	Items
Preliminary Task Development Worksheet	MIL-M-63035(TM)	Task, Equipment, Tools and Test Equipment, Personnel Reqs., Equipment Condition, References, Preliminary Tasks, Follow-on Task, Task Elements
Training Subsystem Summary Sheet	TRADOC REG 351-9	System Data, Development Schedules for Following Training Products - Technical Manuals, SM/TG/JB, ARTEP, Resident Training Program, Resident Training Equipment, Devices, Training Literature, TEC, Audiovisual, ACCP, Facilities/Ranges, Ammunition, NET. Also, Resource Requirements by Fiscal Year.
LSAR Input Data Sheets A through J	MIL STD 1388-1	End Item Maintenance Requirements, Reliability and Maintainability, Summary of Maintenance Task Data, Maintenance and Operator Tasks, Training Materiel Description, Facility Description, Skill Evaluation, Supply Support Requirements
BOIP Feeder Data Sheet	AR 71-2	Description of End Items to be Entered into Inventory, Items to be Replaced
QQPRI Report Part 1	DARCOM P-750-16	Description of MOS, Qualified or to be Qualified During the Development Process

2.2 INTERVIEW ACQUISITION PARTICIPANTS

The review of the LCSMM documents identified prescribed requirements pretaining to the area of early training estimation. To identify what was actually done, interviews were conducted with several of the likely participants in early training estimation. Table 2-5 summarizes the organizations that were contacted during these interviews. The major finding of these interviews was that little, if anything, is typically done in the area of early training estimation prior to Milestone 1. The only activity which takes place during this period is the inclusion of some pro forma statements of training requirements which are included in system requirements documents such as the Letter of Agreement (LOA) despite the fact that several regulations, particularly the newer regulations, such as TRADOC Reg 351-9, indicated that several training-related activities should take place during this time frame. Three reasons were identified for this lack of early training estimation:[1]

(1) Lack of a Systematic Flow of Information Among Participants in the Acquisition Process - To develop estimates of training requirements, training developers require information on actual or estimated systems functional requirements and design concepts as soon as they are generated, and to maintain the accuracy of these estimates, these same training developers must be quickly informed of design changes and updates. A

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[1] A more recent review by Adelman et al. (1982) has indicated that these problems still exist.

Table 2-5. Organizations Interviewed During Task 1

Location	Organizations/Individuals Interviewed
Air Defense School, Fort Bliss, Texas	• Director of Training Developments • Director of Combat Developments • Division Chief, Short Range Air Defense • Division & Assistant Division Chief, Patriot and Nike Hercules • Patriot Project Manager for Training • Educational Specialist, ROLAND • Educational Specialist, SPAs • ROLAND Project Officer, DTD • Associate TSM, Patriot • Associate TSM, Roland • Associate TSM, DIVAP
Armor School, Fort Knox, Kentucky	• Associate TSM, XMI • Staff of Directorate of Combat Developments • Staff of Directorate of Training Developments
Redstone Arsenal, Huntsville, Alabama	• Chief of New Equipment Training, Patriot • Chief of Training Developments, Patriot • Chief, New Equipment Training Branch • Chief of Training Developments, ROLAND
Army Training Support Center (ATSC) Fort Eustis, Virginia	• Staff of ATSC
Training Developments Institute, Fort Monroe, Virginia	• Training Specialist Overseeing Transfer of Information on New Training Technologies
Signal School, Fort Gordon, Georgia	• Director of New Equipment Analysis Division and Staff • Director of Combat Developments and Staff • Training Analysts, Directorate of Training Development
TRASANA, White Sands Missile Range	• Staff, Training Effectiveness Analysis Division

Table 2-5 (continued)

Location	Organizations/Individuals Interviewed
Army Logistics Management Center, Fort Lee, Virginia	• Staff, LAMC
DARCOM, HQ Alexandria, Virginia	• Staff of Associated Directorage for ILS
MRSA, Lexongton-Bluegrass Army Depot, Kentucky	• Staff of Logistics Engineering Branch
TRADOC, HQ Fort Monroe, Virginia	• Director of Human Dimensions and Staff • Staff of Deputy Chief of Staff for Training (DCST) • Staff of TRA

functional requirement defines what a particular design must do to accomplish a specific mission need. Unfortunately, under current practices and procedures, training developers do not receive information on system functional requirements and design concepts in any systematic format, nor is there any formal mechanism through which they can obtain information on system updates.

In addition to the information flow problems which cut across functional areas, there were additional information flow problems among individual training organizations. More specifically, there was a large amount of redundant data development and data collection among training organizations, particularly during the early phases of the acquisition process. System developers and TRADOC organizations did not have the capacity to share information. This led to unnecessary duplication of effort. As a result, different training-related organizations often were not "singing from the same sheet of music."

(2) Lack of Estimation Procedures/Aids Appropriate to the Design Process - Even if training developers were receiving accurate and timely information on early system concepts, current deficiencies in training estimation aids and procedures preclude the early estimation of training resources. Current training technologies are designed to be applied with the type of detailed data and the types of analytical questions which are relevant to later phases of the acquisition

process. These technologies cannot address the special requirements of the early phases such as the identification of comparable existing equipment, the generation of tasks for systems whose hardware has not yet been built, and the rapid estimation of training resources and costs and other evaluation criteria.

(3) Lack of Systematic Technology for Rapidly Evaluating Training Alternatives - Currently, there are no systematic procedures for rapidly assessing the training resources, cost, and efficiency/effectiveness of training alternatives. In addition, there are no techniques for quickly conducting trade-off and sensitivity analyses, and asking "what if" types of questions.

2.3 REVIEW PSYCHOLOGICAL ASPECTS OF DESIGN PROCESS

During this subtask, psychological research relating to engineering design was reviewed. The goal of the review was to identify general guidelines for SDT software development. The review focused on the individual cognitive processes involved in system design and attempted to identify features that should be included in the SDT to facilitate the system development process.

The review began with the search for a general cognitive model which could be used to describe the design process. Ramsey and Atwood's (1979) scheme for describing the problem solving process was determined to be the most suitable framework. Using the framework provided by this scheme, problem solving aids relevant to each stage of the problem

solving process were identified through a review of the problem solving literature. The implications that each of these limitations had for the SDT were then assessed and documented. A summary of this analysis is provided in Table 2-6. While it was possible to incorporate some of the features of the problem solving aids into ETES automated tools, in many cases it was found that the problem solving aids were not relevant to the types of procedures which were eventually included in ETES.

Table 2-6 PHOBLEM-SOLVING AIDS RELATED TO ETES*

Aiding Mechanism	Description	Comments	Principal References	Implications for SDT
Alternative Evaluation	These aids may either automate the user's evaluation criteria, require the user to use established criteria, or simulate the results of actions that do not have well established evaluation criteria.	Except for aids that automate the user's evaluation criteria, these task aids are task-specific. Most useful if the task is not well-defined or if a large number of evaluation criteria need be considered.	Brown et al (1975) Hormann (1967) Rapp (1972) Smith, H. T and Crabtree (1975)	SDT must be capable of feeding into these alternative evaluation aids.
Alternative Generation	These aids are primarily used to generate alternatives that the user would not normally consider or, for extremely well-defined tasks, to present algorithmically determined alternatives.	Except for well-defined task domains, where they may have very little impact, they are difficult to construct. Can be cost-effective for training applications, but generally are of limited use in complex problem-solving tasks.	Baldwin & Siklossy (1977) Gagliardi et al (1965)	SDT must describe design options. However, SDT will not be directly involved in generating design options.
Automatic Action Execution	Such aids permit the user to name the desired action without explicitly carrying out the steps involved in its execution.	Most useful when the results of applying an action do not impact subsequent problem-solving actions. If this is the case, the user may need sophisticated alternative evaluation heuristics.	Carlson & Hodgson (1977) Hanes & Gebhard (1966) Pulfer (1971)	ETES application programs must allow for automatic action executions whenever possible.
Automatic Takeover	This type of aid functions as an automated decision maker that is able to select alternative actions on the basis of prior observations of the human decision maker's behavior. Although allocation of control to this aid occurs automatically, whenever some criterion of correspondence between predicted and observed human behavior is reached, voluntary turnover of control is also possible.	Although demonstrated to be effective in some contexts (e.g., control tasks), the range of tasks in which this is appropriate is not well understood. User acceptance may be low and should be carefully examined.	Freedy et al (1972) Steeb & Freedy (1976)	SDT must be capable of generating automatic "help" queries when user makes major errors.
Backtracking	Such an aid allows the problem solver to "undo" the effects of recent actions and return to an earlier state of the problem-solving process without actually starting over.	Useful in tasks where it is possible to "undo" recent actions. Can improve performance at relatively little development cost.	Carlson & Hodgson (1977) Michie et al (1968) Teitelman (1972)	SDT must have capability of allowing user to return to previous frames.
Better Weighting of Unreliable Data	This aid re-codes low-fidelity data into a form that is more readily usable by the problem solver.	Depends on the ability to accurately recode low-fidelity data.	Topmiller (1968) Howell & Gettys (1968)	If possible, SDT must clearly distinguish between estimated and actual data.
Change of Problem Representation	Typical implementations of this aid present problems as isomorphic variations of more standard problem representations. It is intended that this will aid the problem solver in selecting an appropriate and efficient problem formulation.	Most useful in well-understood tasks. An inappropriate representation may seriously degrade performance.	Chesler & Turn (1967) Smith, H. T. (1974) Newsted & Wynne (1976)	Not applicable to ETES.
Decision Consistency Improvement	This type of aid assists the users applying their own decision strategies consistently in cases in which these strategies are complex.	Useful for expert problem solvers in well-defined tasks. Including sufficient versatility to adapt to individual users may be difficult.	Davis et al (1975) Freedy et al (1976)	Not applicable to ETES.
Decision Strategy Improvement	Such aids assist the user in applying problem-solving techniques that would not normally be considered or known.	Useful in well-defined tasks in which optimal, or near optimal problem-solving techniques are known, or in tasks in which general heuristics, such as problem reduction, are applicable. Requires detailed knowledge of the task.	Caruso (1970) Gagliardi et al (1965) Rogers et al (1964) Wolde (1969)	Not applicable to ETES.
Decomposition and Recomposition	This type of aid allows the user to divide the original problem into subproblems. The solutions of the various subproblems are then combined into a solution to the original, larger problem.	Useful only if a task can be decomposed into independent subproblems. Requires a good understanding of the task.	Krolak (1971)	ETES must be composed of a set of distinct aids and procedures.
Disruption of Psychological Set	Such an aid is intended to disrupt any bias or "sets" that the user may employ and thereby stimulate more creative or novel problem-solving attempts.	Potentially useful, but may disrupt an appropriate "set."	Stewart (1976)	Not applicable to ETES.

*Table derived from Ramsey and Atwood.

Table 2-6 (continued)

Aiding Mechanism	Description	Comments	Principal Reference	Implications for SDT
Extended Memory	This aid allows the user to store and retrieve problem-relevant information. This information may initially be generated by the user or by other problem-solving aids, such as aids for alternative generation and evaluation.	Very useful in almost all tasks. Success is related to the ease of retrieval from external memory	Balzer & Shirey (1968) Newsted & Wynne (1976) Smith, H. T. & Crabtree (1975)	SDT, being a data base management system, must have extensive extended memory capabilities.
Lockout	In an interactive problem-solving situation, this technique restricts the problem solver's access to the computer for some period of time after the presentation of the results from the current request for information.	Although demonstrated effective in some contexts user acceptance was low. The tradeoff between user acceptance should be carefully considered.	Boehm et al (1971) Seven et al (1971)	May be necessary in SDT in cases where two or more users attempt to access and modify the same data simultaneously.
Rapid Trial-and-Error	This aid allows the user to rapidly and easily examine the consequences of alternative action by simulating their application	Easily implemented in well defined tasks. May offset inadequacies in decision strategy improvement aids.	Balzer & Shirey (1968) Carlson & Hodgson (1977) Rapp (1972) Wilde (1969)	Whenever possible, sensitivity analysis procedures should be included in SDT

*Table derived from Ramsey and Atwood.

SECTION 3 - TASK 2: DEVELOP METHOD FOR SYSTEM CONCEPT DESCRIPTION

During this task, five major activities were accomplished. First, as recommended in the statement of work, automated soft'are requirements analysis tools were reviewed to determine if any of these tools could be used to develop and document early system descriptions. When this review proved unfruitful, automated data base management tools were then examined. This analysis did prove to be fruitful as evidenced in the current SDT which is a microcomputer-based data base management system.

Third, recent research in the area of human computer interaction was examined to identify general guidelines which could be used in the development of the SDT.

Fourth, the SDT was developed in accordance with the general requirements for early training estimation identified in Task 1 and the human-computer guidelines developed in the third subtask.

Fifth, the SDT was applied to the Single Channel Ground Activated Radar System (SINCGARS). More details on each of these five activities are presented in the sections which follow.

3.1 REVIEW REQUIREMENTS ANALYSIS TOOLS

The review of requirements analysis tools was conducted in a three-stage process by DRC's software engineering group. During the first stage, DRC surveyed government reports, IEEE Software Engineering Transactions, and other trade publications to determine what tools were available in the area of requirements analysis. Fortunately, a comprehensive review of requirements analysis tools had just been completed by Devorkin and Obenodorf (1979). Further investigation indicated that this report contained all requirements analysis tools with sufficient maturity for possible use in the SDT.

During the second phase of the review, the methodologies listed in Devorkin and Obendorf were reviewed in more detail. Each review began with an examination of the available literature on the methodology. Following the literature review, individual users were interviewed by phone. With the aid of user comments and knowledge of the SDT requirements, criteria were developed for identifying methodologies with a high degree of potential application to the SDT. The evaluation criteria were as follows:

1. Applicability. The methodology must be capable of building a data base of the conceptual information normally available during the early phases of a developing or evolving system. This data base must be capable of refinement as more specific system information becomes available. It must be capable of describing requirements, design concepts, human tasks, and training program elements.

2. Understandability. The methodology must be capable of being understood by the types of "personnel" who are likely to use the SDT.

3. Demonstratability. The methodology must have been applied to a number of different types of projects.

4. Transportability. The methodology must be capable of being implemented at a minimum of cost on standard business processors used in military/ government agencies.

5. Training. The methodology must have an existing formal training program available to potential users.

6. Sponsorship. The methodology must have a specific government agency, university or industry committed to enhancing the methodology to meet additional user needs as they become known. The methodology must reside in the public domain.

While investigating the first few methodologies, it became evident that there were two main thrusts in the area of requirements definition methodologies. One thrust emphasized graphics representation, primarily through functional flow block diagrams, as a means of specifying relationships between system elements. Another thrust emphasized a high level conceptual language as the mechanism for specifying relationships between these system elements. Because there was good deal of overlap between the tools within each of these two thrusts, particularly among the language-based tools which are all basically more advanced

derivatives of earlier work conducted by the ISDOS project at the University of Michigan, it was decided that the tools listed in Devorken and Obendorf would be evaluated in terms of the six criteria listed above, and that the tool in each of the two major thrust areas with the highest evaluations on these criteria would be selected for further analysis in the third stage of the review.

Table 3-1 displays the requirements analysis tools which were evaluated during this stage and summarizes their assessment.

The two tools selected for further analysis were the ICAM Definition Language or IDEF, which was determined to be the best graphics-based tool, and the Problem Statement Language/Problem Statement Analyzer, which was selected as the best language-based tool.

During the third stage of the review, these two tools were examined in even greater detail. As this review was being conducted, it became apparent that the requirements analysis could not provide the vehicle needed for the SDT. There were two reasons for this.

First, the requirements tools did not appear to be suited for the types of uninitiated users who would utilize the SDT. This was not surprising when one considers that all of these tools were specifically designed to describe software requirements for large complex systems. Hence, they are designed to be utilized by technical personnel who have fairly sophisticated backgrounds in software development. (The tools were designed by software specialists for software specialists).

Table 3-1

REQUIREMENTS METHODOLOGIES AND RESULTS OF PRELIMINARY ASSESSMENT

Methodologies*	Preliminary Assessment	Requiring Further Investigation
Computer-Aided Design and Specification Tool (CADSAT)	Tool is derived from PSL/PSA but lacks continuing support by a government agency	no
Design Analysis System (DAS)	Tool has insufficient history of usage and is intended for in-house usage at Hughes	no
Digital System Development Methodology (DSDM)	Tool is not automated and has insufficient history of usage	no
Echo Range Methodology	Tool has insufficient history of usage and is geared for use for sophisticated users	no
Higher Order Software (HOS)	Tool is highly mathematical and not geared for use by uninitiated users	no
ICAM Definition Language (IDEF)	Selected as best representative of graphics-based tools	yes
Input/Output Requirements Language (IORL)	Tool is geared for use by rather sophisticated users	no
Martin Marietta System Design Methodology	Tool has insufficient history of usage and is directly derived from PSL/PSA	no
Program Specification *Language/Program* Specification Analyzer (PSL/PSA)	Selected as best representative of language-based tools	yes
Requirement and Development Language/Requirements and Development Analyzer (RDL/RDA)	Tool is in development stage and is directly derived from PSL/PSA	no
Software Factory	Tool is currently not a comprehensive automated system	no
Software Requirements Engineering Methodology (SREM)	Tool is derived from PSL/PSA but does not have the user history that PSL/PSA has had	no
Structured Analysis and Design Technique (SADT)	Tool is not automated. It is actually more of a methodology than a tool. Best features of tool are contained in IDEF.	no
Xerox System Methodology	Methodology is currently under development and not yet transportable.	no

*List derived from Devorkin and Obendorf (1979).

At a slightly more conceptual level, another factor contributing to the complexity of the requirements analysis tools is that they are designed to be extremely flexible tools which can be utilized to describe <u>any</u> type of system. This type of flexibility necessitates a certain degree of abstractness. This high degree of flexibility and its associated abstractness may actually be a hindrance in describing data for developing weapons systems since such data tends to be similar across systems.

Second, while requirements analysis tools deal with an important aspect of early training estimation (i.e., system description), they are not really geared for dealing with other important ETES related problems; namely, the update and refinement of these system descriptions and their communication to a wide range of participants in the acquisition process

3.2 REVIEW DATA BASE TOOLS

When the investigation of requirements analysis tools proved to be unfruitful, the focus turned to automated data base management systems (DBMSs), as a mechanism for storing and describing developing system descriptions. Generally, DBMSs fulfill the SDT evaluation criteria of applicability, understandability, demonstratability, transportability, training, and sponsorship that were identified in Section 3.1. In addition, most DBMS have the following advantages for the SDT:

1. The DBMSs are designed to store many data items that are related to one another The SDT consists of many data items with complex interrelationships. Therefore, DBMS technology facilitates the development of the SDT.

2. DBMSs allow data to be centrally located and controlled. This simplifies data sharing among multiple users.

3. They can be fitted with data access aids that are easy to use. These aids allow a user to input, modify, delete, and output data using "user-friendly" techniques such as English-like phrases and commands.

4. Access to data items can be restricted. unauthorized users cannot view, modify, delete, or output restricted data items.

5. The format of a data item is independent of the computer program that is accessing it. This is significant if future software systems--other than the SDT--wish to access the data in the SDT data base.

3.2.1 Overview of DBMS Concepts

Before examining the results of the review of DBMSs, it may be helpful to review definitions and key features of the DBMS concept.

An automated data base management system may be defined as a computerized and integrated collection of stored operational data used by the applications groups of a particular enterprise[1]. The key word in this definition is "integrated." The data elements of a system are likely to have relationships or associations which one could use to link these elements to one another. A data base is integrated when it incorporates information on these relationships as well as information on the data elements themselves. This information can be used to store and retrieve data. It should be noted that, strictly speaking, a data base need not be resident in a computer or its associated media. However, all <u>automated</u> data bases will be stored on a computer or related media and all modern DBMSs are automated. It is clear that only an automated data base can meet the storage and retrieval requirements of the SDT. The term "operational data" is used to refer to data which is pertinent to the ongoing activities of an enterprise. Operational data excludes input data, work queues, output data (such as messages or reports) or any other form of temporary information.

- Advantages of a Data Base Management System

The major advantage of a data base management system (DBMS) is that it provides the enterprise with integrated, centralized control of its operational data. This centralized control can, in turn, (1) reduce redundancy in stored data, (2) avoid inconsistency in stored data, (3)

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[1] This definition is a modification of an existing definition by Engels (1971).

allow for greater sharing of data, (4) permit standards to be enforced, (5) permit security restrictions to be applied, (6) permit a greater capability for checking and maintaining data, and (7) provide "data independence." Data independence is achieved by maintaining an internal structure of the data which is independent of the individual applications of the data and individual user viewpoints. This data independence may be contrasted with data dependent systems in which the way data is stored and the way it is accessed are dictated by the structure of the applications.

- Data Base Management System Features

Perhaps the best way to describe the essential features of a DBMS is to outline an "architecture" for a typical DBMS. Such an architecture is displayed in Figure 3-1. This architecture is taken directly from Date (1977). DBMS architectures are typically divided into three general levels: internal, conceptual, and external. The internal level is concerned with the way in which the data is actually stored physically. The external level reflects the users' view of the data. The conceptual level provides the medium for linking the internal and external views. The conceptual model provides a general community view of the data base since it contains an abstract representation of the entire data base. This community view is to be contrasted with the external views of individual users who typically will only have a view of a portion of the data base.

Perhaps another way to describe these three different levels of a DBMS is to refer to the structures that psycholinguistics uses to describe human language. The external

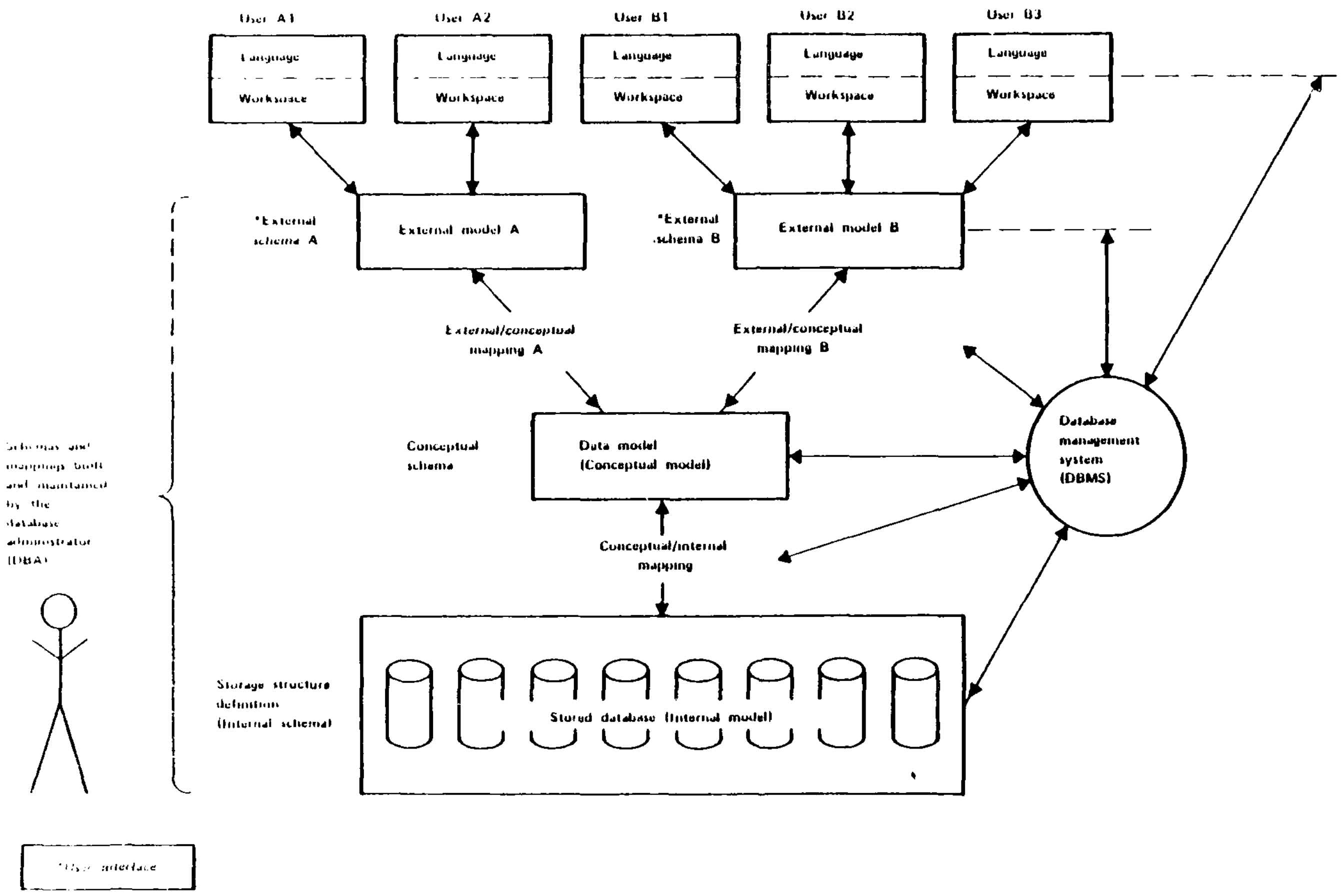

Figure 3-1 AN ARCHITECTURE FOR A DATABASE SYSTEM

*Figure Taken from Date (1977)

view of a DBMS can be construed as being roughly analogous to what psycholinguistics describe as the "surface structure" of language, while the conceptual level can be construed as being analogous to the "deep structure" of language and the internal structure can be construed as being roughly analogous to the physical structures in the brain for representing speech.

It is possible for each external user to have his own "language" for utilizing the data base, although in many cases, all or a large number of users can use the same language.

The conceptual model is defined by a conceptual schema which includes a definition of each of the various types of conceptual information in terms of content only (storage or access features are not described). Thus, the conceptual model provides the definition of the total data base content. The conceptual model is critical in that all other aspects of the DBMS are affected by the conceptual model. It has a major effect on the format and structure of the data sublanguage which is used to store, update, and retrieve information from the data base.

3.2.2 Process and Results of Reviewing Data Base Management Techniques

Review of data base management systems for the SDT occurred in a four step process. First, existing mainframe/ microcomputer data base management systems were reviewed. This review did not identify a data base which could meet ETES requirements. Second, existing micro-computer based

data base management systems were reviewed. While no off-the-shelf microcomputer based data base management system was identified which could meet the ETES requirements, a concept was developed for developing a tailored micro-computer-based data base management system which could specifically meet ETES requirements. Third, hardware/software was identified for implementing this concept. Fourth, concurrent with the review of mainframe databases existing military data bases containing training related information was reviewed to assess their applicability to the SDT. None of these existing data bases met ETES requirements.

3.2.2.1 Review of Mainframe/Microcomputer Based DBMSs

Fifty-one (51) commercially-available mainframe/mini-computer based DBMSs were surveyed through a study of DATA PRO reports (70E-01B-61a and D30-100-002) and other literature. Table 3-2 summarizes the characteristics of the 51 DBMSs that were surveyed. Each data base is described in terms of six basic characteristics: Vendor of the DBMS, Supporting Hardware, Approximate Usage, Primary Data Organization, Approximate Price, and Applicability to SDT.

"Vendor of the DBMS" refers to the company that distributes the DBMS. "Supporting Hardware" refers to the computer hardware configuration on which the DBMS will operate.

"Approximate Usage" is an estimate of the number of installations of the DBMS. It is based on the following scale:

Table 3-2 Characteristics of Commercially Available Main-Frame/Mini-Computer Based DBMSs.

DBMS	Vendor of the DBMS	Supporting Hardware	Approximate Usage	Primary Data Organization	Approx. Price	Applicability to SDT
*ADABAS	Software AG of North America	IBM: 360,370, 303x, 4300	Moderate	Network	$2500/ month $40-160K	Very high
ADMINS/II	Admins, Inc.	DEC: PDP-11, VAX-11	Very low	Relational	N/A	Low
AMBASE	Amcour Computer Company	DEC: PDP-11	N/A**	N/A	$16.5K	Moderate
BASIS	Battelle, Columbus Laboratories	IBM; CDC; Cyber; Univac; DEC	Very low	Relational-like	$38K	Moderate
CREATE	Complete Computer Systems	Data General: NOVA & Eclipse	Very low	N/A	$18K	Moderate
*DATACOM/DB	Applied Data Research, Inc.	IBM:360,370	Low	Relational	$47-57K	Very high
DATA DEMON	Gemini Information Systems, Inc.	Perkin-Elmer; IBM: Series/1	Very low	N/A	$1000/ month $17.5K	Low
DBM-1	Condor Computer Corp.	Cromenco: System/3	Very low	N/A	$10K	Low
DBMS	Prime Computer, Inc.	Prime: 400 & 500	N/A	Network	$20K	Low
DBMS 2	EGS Systems, Inc.	Modular Computer: MODCOMP	Very low	N/A	N/A	Very low
DBMS-10	DEC	DEC: System-10	Low	Network	$30K	High
DBMS-11	DEC	DEC: PDP-11	N/A	Network	$16.5K	Low
DBMS-20	DEC	DEC: System-20	Very low	Network	$30K	High
DBMS-300	Compudata Systems, Inc.	DEC: 300 Series	Very low	N/A	$100/mo $5K	Very low
DBMS-990	Texas Instruments, Inc.	TI: DS990, Models 6 & 8	N/A	N/A	$2K	Very low
DL/I DOS/VS	IBM	IBM: 370, 303x, 4300	High	Hierarchical	$434/mo	High
DMS II	Burroughs Corp.	Burroughs: B 700 or 800	Low	Network	$23.25K	High
DMS 90	Sperry Univac	Univac: Series 80 or 90	Very low	Network	N/A	Moderate
DMS-170	Control Data Corp.	CDC:6000; Cyber 70, 170, 700	Very low	Network	$730/mo	High
DMS-1100	Sperry Univac	Univac: 1100 Series	Moderate	Network	N/A	High
DMS/1700	Dedicated Systems, Inc.	Burroughs: B1700	N/A	N/A	$5K	Low
DNA-Data Base Manager	Exact Systems & Programming Corp.	DG: Nova or Eclipse	Very low	N/A	N/A	Very low

*DBMS selected for further study.

**Not available.

Table 3-2 (continued)

DBMS	Vendor of the DBMS	Supporting Hardware	Approximate Usage	Primary Data Organization	Approx. Price	Applicability to SDT
DPL	National Information Systems, Inc.	DEC: System 10 or 20	Low	Hierarchical	$965/mo $38-47K	High
DRS/XBS	A.R.A.P.	IBM, DEC, Univac, CDC	Low	Network	$22-60K	High
EASE DBMS	Bloodstock Computer Services, Inc.	DEC: PDP-11	Very low	N/A	$6.5K	Low
GIS/2	IBM	IBM: 360 or 370	N/A	Hierarchical	$520-970/mo	Moderate
IBDB	Tesseract Corp.	IBM: Series/1	Very low	N/A	$4.1K	Low
*IDS—I/II (DM-IV)	Honeywell Info. Systems, Inc.	Honeywell: Series 6000 & 60 Level 66	High	Network	$400-$2K/mo	Very high
*IDMS	Cullinane Corp.	IBM: 360,370, 303x, & 4300	Moderate	Network	$50K/yr	Very high
IDOL	Science Management Corporation	Wang: 2200; IBM: Series 1	Low	N/A	$364/mo $9500	Moderate
IMS	IBM	IBM: 360,370, 303x, 4300	Very high	Hierarchical	$1045/mo	High
Infoflex DBM	Interactive Info. Systems, Inc.	DEC: Datasystem 500 Series	Very low	N/A	$12K	Low
INFOMEDIA	Mead Technology Laboratories	IBM: 360 or 370	N/A	N/A	$2000/mo $140K	Low
INFOTRIEVE	Educational Data Systems	EDS: Point 4; DG: Nova	Very low	N/A	$2000	Moderate
INGRES	INGRES, Inc.	DEC: PDP-11	Low	Relational	N/A	Low
IQ/NET	Infodata Systems, Inc.	IBM: 4300	N/A	Network	$40K	Moderate
INQUIRE	Infodata Systems, Inc.	IBM: 360, 370	Low	Network	$70-150K	High
MADMAN	G.E. Company	DEC: PDP-11	N/A	Relational-like	$20K	Low
MIDMS	National Technical Info. Service	IBM: 360	N/A	N/A	$450	Moderate
MINDS	Minnesota Datasystems, Inc.	BTI: 4000, 5000, or 8000	Very low	N/A	$3-5K	Low
*MODEL 204	Computer Corp. of America	IBM: 360, 370, 303x, or 4300	Very low	Network	$90-150K	Very high
OASIS	University of Windsor	IBM: 360, 370, or 303x	Very low	N/A	$30K/yr	Low
ORACLE	Relational Software, Inc.	DEC: PDP11 or VAX	N/A	Relational	$48-96K	Moderate
OS 200 DB	Honeywell	Honeywell: 200 or 2000	Very low	N/A	Bundled free with Hardware	Very low
PLUS/4	Century Analysis, Inc.	NCR: 101 or above	N/A	N/A	$10K	Low
QCRT	The Management Group, Inc.	IBM: 360 or 370; Honeywell: 6000	Very low	N/A	$25K	Moderate

- Very high - greater than 1,500 installations,
- High - 1000 to 1,499 installations,
- Moderate - 500 to 999 installations,
- Low - 100 to 499 installations, and
- Very low - less than 100 installations.

It infers a rough measure of the popularity of a DBMS within the computer-used community. However, this inference does not imply that a greatly used system is better than one of less usage.

"Primary Data Organization" is the logical structure of the data base at the conceptual level. The structure can be relational, network, hierarchical, or a combination of these three. However, only the most commonly referenced structure is listed.

"Price" refers to the basic system purchase price that was quoted to DATA PRO in late 1980. The purchase price generally includes an unspecified monthly maintenance charge. Monthly or yearly lease/rental plans are occasionally included.

The column entitled "Applicability to SDT" is a composite of the 12 SDT Requirements that were identified for a mainframe data base management system. Each DBMS was examined to determine how many of these 12 requirements it fulfilled. The scale used was as follows:

- Very high - All 12 requirements fulfilled,
- High - 9 to 11 requirements fulfilled,
- Moderate - 5 to 8 requirements fulfilled,
- Low - 3 to 4 requirements fulfilled, and
- Very low - 2 or fewer requirements fulfilled.

The applicability factor is the deciding factor for selecting DBMS candidates for the SDT. Only those DBMSs that ranked very high (fulfilled all 12 SDT requirements) were selected for further analysis. These DBMSs are marked with an asterisk (*). The seven DBMSs that were selected for further analysis were ADABAS, DATACOM/DB, IDS-I/II (DM-IV), IDMS, MODEL 204, RAMIS II and SEED. Each of these DBMSs fulfilled the 12 SDT requirements.

At this point, an attempt was made to identify which mainframe of microcomputer DBMS would be available to a wide range of ETES users -- the intent being to select the data base from the seven finalists which would run on most of the hardware owned by ETES users. This attempt to identify a common mainframe or minicomputer for ETES users was not fruitful -- a variety of different machines were used across user sites. Many users did not have mainframe or minicomputer nor did they have access to one. Furthermore, since the cost of obtaining these machines was high, it appeared unlikely that they could obtain one in the future.

3.2.2.2 Review of Microcomputer Based Data Base Management Systems

As the limitations of the mainframe or mini based DBMSs became evident, alternative configurations for the SDT data base were examined. One configuration which was identified as having considerable merit was the distributed processing configuration. In the distributed processing configuration, a centralized data base for each weapon system (or weapon system alternative) would be stored on a mainframe computer. At periodic intervals, users would transfer a copy of the data base from the mainframe to a local microcomputer. Once on the micro, users would perform standard data base management functions (input, output, modify). Thus, all major data base management functions could be performed independently on the microcomputer. Once users have completed their activities with the data base, they could transfer the updated version to the mainframe. A detailed audit trail would be kept for each weapon system so that users can systematically track and assess system changes. The distributed architecture has several important advantages over other configurations. Specifically, it (1) minimizes computer resource requirements (the average user is only required to purchase the microcomputer), (2) minimizes on-line computer charges, (3) allows users the flexibility of conducting their own independent analyses, and (4) provides capabilities for the maintenance of a centralized data base, thus maintaining data integrity.

After discussions with the COTR, it was decided that the SDT would be designed to meet the requirements for a distributed processing architecture and the search began for a

microcomputer-based data base management system which would support this configuration.

Several of the most popular and widely used microcomputer based data base management systems (for example, dBASE II, MDBS III) were examined to determine if any of these data bases could meet the ETES requirements identified in Section 2 and 3.1. This review indicated there were two major problems with existing off-the-shelf microcomputer based data base management systems which limited their applicability to ETES. First, all of the micro-computer based data base management systems used a query language to access the data and obtain output. It was felt that these query languages, while considerably simpler than high-level languages, were too complicated for the potential ETES user to learn and/or use. Second, it was felt that these generalized data bases would not take full advantage of the common data elements which are used over and over again in the development of each weapon system (One of the major objectives of ETES was to identify a common set of data elements which could be used across systems). In this sense, the flexibility of these data bases, which would be an advantage in most applications, was considered to be a disadvantage for the ETES application. Recognizing these limitations, it was decided to build a specialized microcomputer-based data base management system which was (1) tailored to meet the specific needs of early task training estimation for Army weapon system and (2) used more "user-friendly" human computer dialogue techniques such as menu selection to access and output data.

3.2.2.3 Selection of SDT Hardware/Software

Once it was determined that a tailored microcomputer-based management system would be used for the SDT, an investigation was conducted to identify the microcomputer and computer languages which would be used for SDT development. As part of this investigation, an attempt was made to identify the brand of microcomputer that was most popular among ETES users in the Army.[2] This investigation indicated that the Apple computers were most popular among potential ETES users. For example, Apple computers were being used by ARI and by several of the TRADOC schools.

Once it was decided that an Apple was to be used, the specific hardware configuration that was to be used to develop the SDT was identified. This configuration is listed in Table 3-3. The Apple III, rather than the Apple II, was selected as the microcomputer to be employed in the SDT because the Apple III had the capability to be used with a external hard disk system. Such a system could provide the memory needed for the SDT data base management functions[3]

To provide a capability for testing the distributed processing capability of the SDT, it was decided to use the contractors (DRC's) mainframe computer (the Honeywell DPS

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2 A more formal attempt was made to identify any Army wide plans to purchase a single brand of microcomputer. This investigation did not produce any fruitful results.

3 Since the SDT was developed, Apple has developed a version of the Apple II, the Apple IIE which can be used with the external hard disk.

Table 3-3 SDT Hardware Configuration.

MICROCOMPUTER CONFIGURATION	MAINFRAME
APPLE III	DPS 8/52
MODEM	
PRINTER	
MONITOR	
FLOPPY DISK DRIVES	
PROFILE MASS STORAGE (HARD DISK) OR ADDITIONAL FLOPPY DISK DRIVES	

8/32) since it provided a low cost mechanism for demonstrating this capability. Because of resource limitations, only a very limited distributed processing capability was to be demonstrated during the ETES development contract. It was decided that the full distributed processing capability would either be achieved in the Man Integrated System (MIST) contract, which is currently integrating ETES with several other ARI MPT projects, or in the ETES implementation contract which was to follow the ETES development contract.

After the hardware configuration was identified, the computer language to be used for the SDT software was identified. PASCAL was selected as the language for developing the SDT and other ETES automated tools because of (1) its widespread usage on both microcomputers and mainframes, and (2) its highly structured nature which facilitates modular program construction and transportability.

3.2.2.4 Past Efforts In Developing System-Specific Data Bases

Concurrent with the examination of data base management technologies, past efforts in developing system-specific human resource data bases were examined. Table 3-4 lists the major data bases that were examined during this process. More details on each of these data bases are provided in the section which follow.

Table 3-4

PAST EFFORTS AT HUMAN RESOURCE DATA BASE DEVELOPMENT*

(1) Logistics Support Analysis Record (LSAR)

(2) Unified Data Base of Air Force Human Resource Lab

(3) Consolidated Data Base (CDB) of Navy/Army HARDMAN Projects

(4) Structured Approach to Training (SAT) Program for the B1-Bomber

(5) Navy Enlisted Professional Information Support System (NEPDISS)

*Efforts are listed in terms of their decreasing relevance to the ETES SDT.

- o Logistics Support Analysis Record

One major effort which is closely related to the objectives and goals of the SDT is the Logistics Support Analysis Recore (LSAR). MIL-STD-1388 states that the goal of the LSAR is to be the "single source of validated, integrated, design-related logistic data pertinent to the acquisition program."

Table 3-5 lists the system elements that are described by the LSAR and the major weaknesses of the current LSAR in respect to the goals and objectives of the SDT. As Table 3-4 indicates, the LSAR has several weaknesses which limit its use as a comprehensive system description technology for human resource assessment.

First, there are several important system elements (e.g., system functional requirements, collective tasks) which the LSAR does not describe. Failure to describe the system functional requirements is particularly distressing, since these functional requirements provide the foundation on which all other system elements depend. Lack of a systematic description of functional requirements makes it extremely difficult for training developers and others who are tasked with relating their particular system elements to overall mission performance and its associated functions. For instance, it makes it extremely difficult to relate human tasks to mission performance. Given its lack of a capability for describing system functional requirements or projected system elements, it is not surprising that the LSAR is currently not applied during the concept exploration phase of the acquisition process and seldom, if ever, applied during the validation and demonstration phase.

Table 3-5

OVERVIEW OF LSAR AND ITS MAJOR WEAKNESSES

System Elements Described by LSAR

- Equipment (work breakdown structure, work unit code, nomenclature, reliability, maintainability, failure symptoms, failure effect and criticality, maintenance concept)
- Tasks (task code, frequency, elapsed time, skill specialty, man hours, requirements for training equipment, support equipment, tools, task elements, aggregate maintenance man-hour requirements)
- Support and Test Equipment (physical characteristics, associated equipment, associated tasks, associated training, special skill requirements)
- Facilities (associated equipment and tasks, general requirements, lead times, type of construction, utilities, facility unit cost)
- Skills (associated task and equipments, specialty codes, aptitude, rank/rate, special physical and mental requirements, educational requirements, additional training requirements)
- Supply Support (part no. and nomenclature, physical description, associated equipment, allowance quantity, distribution)

Major Weaknesses of LSAR*

- Does not describe system functional requirements
- Does not provide adequate description of operator tasks
- Does not describe task characteristics or performance information
- Does not describe collective tasks
- Does not adequately describe skills
- Does not adequately describe training program elements
- Does not provide mechanism for describing estimated or projected elements
- Is not applied in early phases
- Does not have data base management capability
- Cannot generate tasks or other input data

*Many of these limitations are apparently being dealt within the present LSAR improvement programs.

Hence, its value as a data base to support early human resource assessment is very minimal indeed.

Second, there are a number of other systems elements which are described by the LSAR but are not described adequately or in enough detail (e.g., operator tasks, task characteristics, training program elements skills). The emphasis of the LSAR on maintenance and maintenance tasks is quite obvious. This emphasis makes it extremely difficult to develop or maintain adequate descriptions of operator tasks. For all types of tasks, the LSAR does not fully describe the task characteristics and performance information that is needed by training and/or human factors specialists to adequately assess their components of the system. The training portion of the LSAR places an emphasis on training equipment and devices and ignores other important aspects of the training program (e.g., course modules).

Third, at a more conceptual level, the LSAR does not provide an adequate capability for describing estimated or projected system elements. Such estimates are necessary during the early phases of the acquisition process.

Fourth, the LSAR was not conceived as an automated data base management system description -- that is, as an automated system for describing, updating, and expanding system concepts and communicating this information to system users. It should be noted that the Army, through the DARCOM Materiel Readiness Support Activity, has been a leader in "automating the LSAR." However, this automation apparently refers only to the use of computerized algorithms for aggregating certain LSAR elements or for presenting

printed outputs of reports. It is not designed to be an interactive system. More important, the automated LSAR does not provide for the automated description of system concepts, updates, changes and expansions through a comprehensive data base management system. This is due to the fact that the LSAR does not have a systematic internal structure linking the various system elements to one another.

- Air Force Human Resource Lab Unified Data Base

The Air Force Human Resource Lab (AFHRL) has initiated a program to develop a Unified Data Base (UDB). The goals of the UDB are very similar to the SDT (see Thomas, Newhouse and Hankins, 1980; Thomas and Hankins, 1980). Ultimately, the UDB is designed to provide "a centrally located data base of human resource related information for utilization in the weapon system acquisition process to influence hardware concepts and design." The UDB is to be supported by a Data Generating Technology Data Base (DGTB) which is intended "to generate generic data to fill in the needs of users where the data systems, and likewise the UDB, would leave voids." Thus, the DGTB is somewhat similar to the ETES training estimation aids and procedures.

At the time the ETES review was conducted, UDB development efforts had focused on (1) an assessment of existing historical data bases which would feed the UDB, particularly the projected portions of the UDB, (2) a description of the weapon system design process with respect to the potential use of the UDB, (3) an assessment of user needs in terms of

adequacy of current technology and data[4], and (4) the development of a plan for UDB/DGTB development.

At the time the ETES review was conducted, a description of the actual data elements to be included in the UDB was not available (this was to be developed in future phases of the study). However, by examining the types of historical data bases which are projected to be used by the UDB, it was possible to make some estimates of what it would contain and to assess some of its potential limitations.

These limitations point out the differences between the UDB and the ETES SDT. These differences are actually quite significant despite the similarity in the goals of these two systems (see Table 3-6).

The first limitation of the UDB is its emphasis on maintenance tasks and personnel. The UDB, like the Air Force Coordinated Human Resources Technology, emphasizes maintenance behavior and the use of historical data bases related to maintenance. There is little relevant discussion of the procedures and mechanisms for developing or describing operator tasks or training requirements.

This emphasis on maintenance tasks is closely related to a second limitation of the UDB; namely, its emphasis on aircraft systems and on Air Force data bases. In the Air

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4 In the examination of the utilization of human resource data in tradeoffs, it is interesting to note that lack of information and lack of appropriate analytical tools were seen as two of the major types of limitations on the use of human resource assessment.

Table 3-6
LIMITATIONS OF THE UDB

- Focuses almost exclusively on maintenance tasks.
- Emphasizes aircraft systems
- Does not appear to adequately describe functional requirements, collective or team tasks, task characteristic or performance data, and training program elements
- Is not based upon comprehensive data base management system structure
- Is geared for use by sophisticated users
- Cannot generate tasks and other input data

Force, the role of enlisted operators is much less significant than it is in the Army or Navy. Hence, it is not surprising that the UDB has focused on the maintenance of aircraft systems.

Third, there are number of other system elements which the UDB would appear, at least at the present time, not to describe. These elements include functional requirements, collective or team tasks, task characteristics, and performance data suitable for training and human factors analytical activities, and training program elements. (This failure to describe certain elements would not be critical if the UDB had the proper data base management structure to handle additional system elements. Unfortunately, it appears that it does not have this capability).

Fourth, and perhaps most important, the UDB again does not appear to be based upon a data base structure--that is, a structure which represents the implicit relationships among the various system elements. Such a data base management structure would provide a mechanism for describing the basic structure of a developing system which was independent of the various user viewpoints of the data. This data independence would increase the capability for relating various descriptions of the system to one another, for updating and refining the data, and for adding new elements to the data base in a systematic modular fashion with minimum destruction of existing programming thus providing the basis for a true data base management capability.

Fifth, the UDB appears to be geared for use by technical personnel who have sophisticated analytical and/or computer programming experience--unlike the SDT which is geared for

use by personnel with little background in computers. Because of this difference in emphasis, it is not surprising that the UDB does not specify or deal with the human factors of human-computer interactions as with the SDT, which is specifically geared for utilization by uninitiated users and will attempt to employ the latest guidelines on human-computer interfaces. Because of its lack of consideration of human factors issues, the UDB does not attempt to provide procedures for assisting the user in generating tasks or other input data elements.

- Consolidated Data Base (CDB) of Hardman Methodology

The Navy has a program, called the HARDMAN program (hardware versus manpower procurement), to develop a methodology to systematically assess the manpower, personnel, and training requirements of emerging weapon systems, with particular emphasis on developing predictions for the early phases of the acquisition process. The HARDMAN methodology has been applied to a number of different Navy systems and has been modified for use by the Army and applied to several Army weapons systems. (See Appendix D for a discussion of HARDMAN).

The application of the HARDMAN methodology is supported by the development of a system-specific "data base" which is designed to contain all of the inputs and outputs of each of the steps in the HARDMAN methodology and provide an audit trail for monitoring the data elements which are developed. Table 3-7 lists the data elements described by the CDB. Like the other current human resource data bases, the CDB

Table 3-7

DATA ELEMENTS CONTAINED IN CDB

General System

- Requirements Documents
- Study Plans and Objectives
- Technology Base Studies
- Projected Operational Environment
- System Functions and Performance Requirements
- Program Constraints
- Minimal Essential Elements of Information List
- Audit Trail Files
- Worksheets
- CDB Index
- Predecessor Equipment List and Related Data
- Reference Equipment List and Related Data
- Predecessor and Reference Reliability Data

Manpower*

- Workload Taxonomy
- Indirect Workload Factors
- Task Event Networks
- Manpower Model Data
- Manpower Metrics and Associated Values
- System Manning (MOS, Skill Level, Duty Positions)

Training*

- Task and Skill Data
- Course Catalogue
- Course Outlines
- Course Methods/Media
- Course Costing Data
- Course Scenario Information
- Career Path Information
- Training Concept
- Training Device and Equipment
- Steady State Resource Requirements
- Steady State Course Costs
- Replacement Personnel Requirements
- Task Selection and Assignment Algorithms
- Facilities Requirements

Personnel*

- Career Path Data
- Career Path Statistics (Attrition, Promotion, Upgrade)

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*All elements for predecessor, reference, and baseline systems except where noted.

has several limitations with respect to the SDT requirements.

The major limitation of the CDB is that only parts of it are automated. Thus, it cannot provide a computerized data base management capability. Another major limitation of the CDB is that, like the UDB, it does not contain a systematic scheme for relating the various system elements to one another, a scheme which would be independent of specific input and output requirements. Thus, the CDB is not really a true data base management system since it does not have an automated capability for linking various system elements to another for retrieving data elements.

Finally, the CDB does not provide any extensive automated capabilities for generating input data formats or actual input data elements.

- SAT Program for the B-1 Bomber

The Structural Approach to Training (SAT) program for the B-1 bomber represents a relatively early attempt to develop a system-specific data base to support instructional systems development (see Sugarman, Johnson, and Ring, 1975).

The SAT consisted of two major elements, a data base (the contents of which are displayed in Table 3-8) and two computerized aids. One aid is a sorting model for the storage, retrieval, collating, and updating of mission/function task analyses and supporting data; the other is an analytical model for providing cost and training estimates of the B-1 bomber training system.

Table 3-8

SAT DATA ELEMENTS AND LIMITATIONS

System Elements Described by SAT Data Base

- Tasks (title, task element number, operator behavior, task duration, crew interaction, previous task element, task characteristics, and performance data)
- Control/display information (associated system, synonyms)
- Behavioral objectives (title, initial conditions, concurrent behaviors, performance criteria, enabling and ancillary objectives, operators, interactions, task elements, objective criticality, objective difficulty)

Limitations of SAT Data Base

- Is geared for one specific system
- Is not designed to provide generic data base management capability
- Does not systematically describe system functional requirements and design concepts
- Does not include training program elements in automated portion of the data base
- Is geared for sophisticated users
- Cannot generate tasks and other input data

The SAT data base is interesting in that it is probably the only past effort which has attempted to (1) systematically describe task characteristics in a format which is amenable to the application of automated training aids for determining the tasks to be trained and selecting methods and media, and (2) systematically describe the task performance characteristics of equipment (e.g., relationships of tasks to controls and displays). Such task performance data is critical to human task performance simulation models.

However, despite its desirable features, the SAT data base also has several limitations which restrict its applicability to the SDT. First, the SAT data base elements and programs were specifically designed to fit one system--the B-1 bomber. Thus, all of its task and control/display dictionaries and structures are only applicable to that system. The SAT was not designed to be a generic data base system which could be applied across a wide range of weapon systems.

Second, the SAT does not describe several important system elements such as functional requirements and design/hardware elements.

Third, training program elements are described but not included in the automated data base.

Fourth, the SAT is geared for very sophisticated users with extensive computer experience.

Fifth, the SAT is not structured to assist users in developing input data formats or actual input data elements such as tasks.

- Navy Enlisted Professional Development Information Support System (NEPDISS)

The objectives of the NEPDISS are more limited than the goals of the other human resource data bases described above. The NEPDISS is specifically designed to store and retrieve data related to training program development (see Davis, 1977 for a description). Thus, it is primarily designed to describe task and training data (see Table 3-9). The only description of equipment-related concepts in NEPDISS is in the task statements of the task portion of the data base. Other major limitations of the NEPDISS are its lack of capability for describing projected system elements, its apparent lack of appropriateness for use by uninitiated users, its lack of a capability for generating tasks and other data impacts, and most important, its lack of a true data base management capability for updating and refining system elements.

Despite the weaknesses, it is important to note that the NEPDISS is especially strong in describing task and skill related requirements which are appropriate for training and personnel analysis.

- Other Data Bases

There are a number of other data bases which attempt to deal with some of the issues related to the SDT. For instance, the Consolidated Occupational Data Analysis Program (CODAP) and the Training Developments Information System (TDIS) are Army data bases which also deal with task description. The CODAP focusses on tasks from the perspective of a single MOS while the TDIS focusses on common tasks which are applicable

Table 3-9

NEPDISS DATA LIMITATIONS

- Does not describe system functional requirements. design concepts, training program elements or collective tasks.
- Is geared for use by sophisticated users.
- Cannot generate task and other input data.
- Is not designed to describe projected system elements.
- Does not provide comprehensive data base management capability for updating and refining system elements.

across MOS. However, neither one is geared for use in describing the hardware/software design, tasks, and training characteristics of a emerging weapon systems.

3.3 REVIEW RESEARCH RELATED TO HUMAN COMPUTER INTERACTIONS

One of the major problems surrounding the weapon system design process is the communication and flow of information among the participants in this more general process. The ETES SDT is specifically designed to deal with these communication problems by providing a centralized, automated data base for describing and updating emerging system concepts and providing direct access to this data base to all participants in the weapon system design process. Thus, the SDT provides a systematic vehicle through which the participants in the weapon system design may communicate. To provide a foundation for SDT development recent research related to human-computer interaction was examined. This section describes the results of that examination.

The section is divided into two subsections. The first describes the SDT requirements related to human computer interactions. The second subsection reviews psychological research relating to the process of human computer interactions and summarizes the implications that this literature has for the SDT.

3.3.1 SDT Requirements Related To Human Computer Interactions

Task 1.0 examined the problems in information flow and communication which limited early training estimation. This task indicated that training developers and other participants in the acquisition process are not systematically receiving information on early system concepts and are not being kept abreast of system changes and updates in a timely and systematic fashion. This lack of systematic communication makes it difficult if not impossible to effectively assess training and other human resources, and this lack of assessment, in turn, makes it difficult to effectively manage and control these resources.

In order for the SDT to fill these communications deficiencies, the SDT must itself be designed to facilitate easy and rapid communication with the personnel who will use it. Task 1 indicated that the primary users of the SDT will be personnel from the staff of the training developers, combat developers, and material developers. These personnel are likely to have had little, if any, experience in utilizing computers or computerized data bases. Interviews with current personnel in these organizations indicated that there is also likley to be very little time or resources to train these personnel on ETES-related activities. Thus, it was imperative that the SDT be designed to (1) be utilized by uninitiated users who have no background in the use of computers and computer languages and (2) have minimal training requirements. Fortunately, in recent years there has been a growing body of literature on human-computer interactions and the types of interactions which are

appropriate for uninitiated minimally trained users. This literature is reviewed in the subsections which follow.

Before discussing this literature, it is important to point out that the systematic study of human-computer interactions is a relatively new area of research. Consequently, many of the guidelines discussed in the next section are only rational schemes for dealing with human-computer interactions -- empirical research to support these guidelines is generally not available. However, the conceptual schemes which have been developed do appear to have a high degree of face validity.

3.3.2 Human-Data Base Interaction Literature Review

There have been four major efforts to survey and categorize literature relating to human-data base interactions.[5] More details on these four efforts is presented in the subsections which follow.

3.3.2.1 Martin's Work on Interactive Dialogues

The first comprehensive work in human-computer interactions was conducted by Martin (1973) who documented his work in a book on human-computer dialogues. Martin's book was the first attempt to provide a systematic set of guidelines or human computer interactions. Earlier work had focused on

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5 This research area is also described as the "man-machine interface" (MMI) as well as the human-computer interface or interaction.

the development of guidelines for computer input devices or output devices or computer programming practices but had not systematically covered dialogue or process-related questions.

Martin's basic approach toward conceptualizing the human-computer interactions was to divide human-computer interactions into 18 basic dialogue types and to outline the advantages and disadvantages of each type in terms of types of users and information characteristics.[6] Table 3-10 displays Martin's dialogues types and the estimated applicability to the SDT based upon Martin description of their advantages and disadvantages. As Table 3-10 indicates, the most likely dialogues types for inclusion in the SDT are menu selection dialogues, form-filling, and question and answer dialogues. These were the dialogues which Martin indicated were (1) most appropriate for uninitiated users and (2) would not require extensive development costs or special terminals.

Martin also provides a series of guidelines to consider in selecting input and output devices. Table 3-11 lists the input and output devices covered by Martin. To reduce implementation costs, it was decided that the SDT would utilize existing hardware (see Section 3.2.2.3 for a description of the SDT configuration). This requires that the SDT interactive input device mechanisms be restricted to a keyboard and SDT output devices mechanisms be restricted to a printer and a CRT screen.

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6 Martin presents little empirical evidence to support his concepts (very little work has been done in this area). However, his concepts appear logical and seem to have a high degree of "face validity".

Table 3-10

MARTIN'S DIALOGUE TYPES AND THEIR APPLICABILITY TO SDT*

1. Programming languages

2. English-language dialogue

3. Limit English input

*4. Question and answer dialogues (in which the computer asks the operator a series of questions)

5. Dialogue using mnemonics

6. Dialogue with programming-like statements

7. Computer-initiated dialogues (in which the operator responds to the computer rather than the computer responding to the operator)

*8. Form-filling (in which the operator fills out a "form" on a visual display)

*9. Menu-selection dialogues

10. Build dialogue features into special terminal hardware

11. Dialogues with a light pen for input (or other means of pointing to the screen)

12. Fixed-panel responses (in which the computer responds with one of a standard set of panels)

13. Modifiable-panel dialogues (in which the panels can be modified by the programs)

14. Graphics using chart displays

15. Graphics using symbol manipulation

16. Dialogues with photographic frames

17. Voice answerback dialogues

18. Dialogue via a third party

---

*Items applicable to SDT.

Table 3-II

MARTIN'S CATEGORIZATION OF INPUT-OUTPUT DEVICES AND THEIR APPLICABILITY TO THE SDT

Input	Output
*Keyboard	*Typewriter or printer
Lever set or	Alphanumeric screen
Rotary switches	*Graphics screen
Push buttons	Screen displaying film frames
Light pen for point at screen	Light panel
Finger pointing at screen	Graph plotter
Stylus for drawing	Dials
Plate reader	Voice answerback
Badge reader	Facsimile machine

*Applicable to SDT.

3.3.2.2 Ramsey and Atwood's Work on Human Factors in Computer Systems

Another major effort in systematically assessing human-computer interactions was directed by H. Rudy Ramsey and Michael Atwood in work sponsored by the Engineering Psychology Programs of the Office of Naval Research. Ramsey and Atwood (1979) have developed a conceptual scheme for classifying different areas of research relating to human-computer interactions. Table 3-12 presents this scheme and also indicates which Atwood and Ramsey categories are most relevant to the SDT development. It is important to point out that input and output device questions were less relevant to the SDT because the SDT utilizes existing Apple III input/ output devices.

In discussing user characteristics, Ramsey and Atwood review several past articles which have dealt with the requirements and/or capabilities of uninitiated users. (e.g. Card et al, 1974; Eason, et al 1975; Evans, 1976; Martin, 1973; Nickerson and Pew, 1971; and Thompson, 1971). Atwood and Ramsey indicate that interactions by these users can be facilitated if the computer-initiated or natural language dialogues are used, and they point out that natural language dialogues are very expensive to develop.

As was noted earlier, Ramsey and Atwood indicate that computer initiated dialogue would seem to a much more effective means of communication with uninitiated users, who are exactly the type of users which will utilize the SDT.

Ramsey and Atwood point out that computer-initiated dialogue has several advances. First, this approach to dialogue

Table 3-12

RAMSEY AND ATWOOD'S SCHEME FOR CLASSIFYING HUMAN-COMPUTER INTERACTION INFORMATION*

Description of Ramsey and Atwood Categories	Applicability to SDT
Users: their behavior in general; how to determine the properties of a particular user population, the implications of those properties for the interactive system.	x
Tasks: what tasks users perform; how to determine tasks involved in an application.	x
Requirements analysis: how to analyze information requirements; how to select appropriate types of problem-solving, clerical and user support aids; allocation of basic tasks to user or computer; modeling of user-system interactions; evaluation of basic design.	
Interactive dialogue: properties of different dialogue types; selection of appropriate dialogue type(s); detailed design of command language, system access structures, tutorial aids, etc.	x
Output devices and techniques: properties of display devices; implications of dialogue method for display device selection; selection or design of display device(s); detailed display design, formatting, coding techniques, etc.	x
Input devices and techniques: properties of input devices; implications of dialogue methods for input device selection; selection or design of input device(s).	
Evaluation of system performance: use of subjective evaluations, objective performance measures.	

*Table derived from Ramsey and Atwood (1979).

allows the system to rely on the passive vocabulary of the user (the set of words which the user can recognize and understand), which is typically much larger than the user's active vocabulary (words which the user can generate and use without prompting). Second, it allows the designer to implicitly convey to the user a "mental model" of the system's dialogue structure. The major disadvantage of computer-initiated dialogue is the frequent delay it may produce for experienced users.

Ramsey and Atwood also present a scheme for classifying different types of interactive dialogues, and list the advantages and disadvantages of each type. A summary of this discussion is presented in Table 3-13. Two types of dialogue seem especially applicable to the SDT because of their emphasis on computer-initiated dialogue -- form filling and menu-selection.

Form-filling is often used in situations in which the user's input is dominated by parameter values, rather than commands. Many system attributes involve this type of data. hence, form-filling would appear to be particularly useful as a data input mechanism for data attributes.

Menu selection is described by Ramsey and Atwood as the "archetype of computer-initiated dialogue." Unlike question and answer dialogue or form-filling, all of the times to be selected appear on the screen, and thus the user need only recognize the desired action. Also, a simple menu-selection dialogue ordinarily requires only one user input (on the keyboard or screen), rather than, for example, the series of keystrokes required to type a whole word. Redsdale (1970) reports a study which documented the effectiveness of menu

Table 3-13

RAMSEY AND ATWOOD'S SCHEME FOR CLASSIFYING DIALOGUE TYPES*

Dialogue Type	Description	Appropriateness for SDT
Question-and-Answer	Computer asks questions to which user responds.	Recommended for naive user. Hence, appears to be applicable to SDT.
Form-filling	Computer presents form with blanks. User fills in blanks.	Recommended for naive user. Hence, appears to be applicable to SDT. Faster than question-and-answer dialogue.
Menu Selection	Computer presents list of alternatives, and user selects one or more.	Recommended for naive user. Hence, appears to be applicable to SDT.
Function Keys	User indicates desired action by depressing keys, each of which represents a command, command modifier, or parameter value.	Not recommended for SDT since SDT will be required to use existing terminals.
User-initiated Command Language	User types commands, perhaps using mnemonic abbreviations.	Not acceptable because of emphasis on well-trained users.
Query Language	User inputs questions or data base access procedures to a data base system. System produces response or report.	May be applicable for several SDT functions relating to data retrieval.
Natural Language	Dialogue is conducted in user's natural language (e.g., English).	Not recommended for SDT because of extremely high cost involved and wide range of users using system.
Interactive Graphics	Generation of pictorial displays, ability of user to select displayed entities and spatial locations by pointing or similar nonverbal means.	Not recommended for SDT because of cost and equipment limitations.

*Table derived from Ramsey and Atwood (1979).

selection with naive users. The study indicated that menu selection was especially effective when used as means of obtaining answers to a set of branching questions.

It is especially important to note that menu selection is a highly effective dialogue method for hierarchical search because of its reliance on the user's passive vocabulary and recognition memory. Hence, menu selection is particularly applicable to information retrieval (see Thompson, 1969, 1979 for a more extensive discussion of menu selection as a data retrieval mechanism).

3.3.2.3 Smith's Work on Man-Machine Interface

Another major effort related to the assessment of human-computer interactions was Sidney Smith's (1980) work on the development of guidelines for the man-machine interface in C3 systems. This work was sponsored by the Air Force Electronic Systems Command.

Like Ramsey and Atwood, Smith (1980) has developed a scheme for categorizing topic areas related to human-computer interactions. Table 3-14 displays Smith's schemes and the categories of Smith's work which had the most applicability to the SDT. Selected aspects of Smith's (1980) major report in this area which were relevant to ETES are reviewed below.

- Dialogue Types

Smith, like many other investigators in this area, notes that computer-initiated dialogue types (e.g., form-filling, menu selection) are more appropriate for uninitiated users

Table 3-14

SMITH'S SCHEME FOR CLASSIFYING HUMAN-COMPUTER INTERACTION INFORMATION*

1.0 DIALOGUE TYPE
1.1 Question and Answer
1.2 Form Filling
1.3 Menu Selection
1.4 Function Keys
1.5 Command Language
1.6 Query Language
1.7 Natural Language
1.8 Graphic Interaction

2.0 DATA ENTRY/INPUT
2.1 Position Designation
2.2 Direction Designation
2.3 Data Type
2.4 Entry Formats
2.5 Data Validation
2.6 Data Processing

3.0 DATA DISPLAY/OUTPUT
3.1 Data Type
3.2 Data Density
3.3 Data Aggregation
3.4 Data Coding
3.5 Display Partitioning
3.6 Display Selection
3.7 Data Coverage
3.8 Display Update
3.9 Data Selection

4.0 SEQUENCE CONTROL
4.1 Transaction Selection
4.2 Interrupt
4.3 Context Definition
4.4 Error Management
4.5 Alarms

5.0 USER GUIDANCE
5.1 Status Information
5.2 Routine Feedback
5.3 Error Feedback
5.4 Instructional Aids

6.0 DATA TRANSMISSION/COMMUNICATION
6.1 Data Transfer
6.2 Data Type
6.3 Transmission Control

*Table derived from Smith (1980).

than are user-initiated dialogues (e.g., programming languages). Table 3-15 displays Smith's categorization of the different dialogue types and his estimation of user training and response time associated with each type. Based upon Smith's estimates question and answer, form-filling and menu selection would seem to be the most appropriate dialogue formats for the types of uninitiated users who will use the SDT (response time is not a critical issue for the SDT).

- o Data Entry/Input

In discussing data entry/input topics, Smith mentions some general guidelines that should be considered in the construction of data entry mechanisms. First, an operator should seldom be required to enter the same data twice or enter a data item already entered by another operator. He suggests that the way to do this is to program the computer to maintain context (that is, the computer should be able to access all data related to the user's input). Second, computer systems should be flexible. This means that the user should be able to set his own pace, cancel incomplete transactions, etc.

- o Data Display/Output

Much of the material covered in Smith's discussion on display/ output is redundant with Ramsey and Atwood's work. Hence, it is not repeated here.

Table 3-15

SMITH'S SCHEME FOR CLASSIFYING DIALOGUE TYPES*

Dialogue Type	Required User Training	System Response Time
Question and Answer	Little/None	Moderate
Form Filling	Moderate/Little	Slow
Menu Selection	Little/None	Very Fast
Function Keys with Command Language	High/Moderate	Fast
User-Initiated Command Language	High	Fast
Query Languages	High/Moderate	Moderate
Natural-Language Dialogues	Moderate (potentially little)	Fast
Interactive Graphics	High	Very Fast

*Table taken from Smith (1980)

- Sequence Control

Smith suggests that menu selection might be used as an effective means of providing sequence control for uninitiated users. He also indicates that flexibility is important in sequence control, particularly in interactions which involve the modification of stored data.

- User Guidance

Smith suggests that the fundamental rule in the area of user guidance is that for every action by the user there should be a response by the machine. Such feedback helps maintain user orientation.

3.3.2.4 Sidorsky and Parrish Work on Battlefield Automated Systems

A comprehensive assessment of human-computer interaction is currently being developed by Sidorsky and Parrish (1980) in work conducted for the Army Research Institute. The goal of the Sidorsky and Parrish work is to develop general guidelines for describing and designing battlefield automated systems so that ultimately the interoperatibility of such systems can be increased, and, consequently, user errors can be decreased. Like Smith (1979) and Ramsey and Atwood (1979), Sidorsky and Parrish (1980) have developed a conceptual scheme for classifying information related to human-computer interactions (see Table 3-16). They have also developed a method for systematically assessing the human-computer transactions which currently occur in battlefield systems.

Table 3-16

SIDORSKY'S AND PARRISH'S SCHEME FOR
CLASSIFYING HUMAN-COMPUTER INTERACTION INFORMATION*

1. CONTROL METHODS
1.1 Command Languages
1.2 Menus
1.3 Function Keys
1.4 Hybrid Methods
1.5 Prompt/HELP

2. DISPLAY FORMAT
2.1 Fixed Alphanumeric Displays
2.2 Variable-Length Alphanumeric Displays
2.3 Graphic Displays
2.4 Highlighting

3. DATA ENTRY ASSISTANCE
3.1 Information on Legal Entries
3.2 Unburdening of Input
3.3 Interrupts and Work Recovery

4. MESSAGE COMPOSITION AIDS
4.1 System Design Features
4.2 Format for Alphanumeric Messages
4.3 Graphic Messages

5. DATA RETRIEVAL ASSISTANCE
5.1 Query Method
5.2 Query Structure

6. GLOSSARIES
6.1 Standard Terms
6.2 Character Sets and Labels
6.3 Glossary Availability and Use
6.4 Abbreviation and Coding

7. ERROR HANDLING
7.1 Prevention
7.2 Detection
7.3 Feedback
7.4 Correction/Recovery

8. USER/OPERATOR CONFIGURATIONS
8.1 Operator(s) Only
8.2 Operator(s) and User(s)
8.3 Combined Operator/User
8.4 Operator and User Chains

*Table derived from Sidorsky and Parrish (1980).

The study by Sidorsky and Parrish had just begun at the time of the ETES review, hence they only had developed guidelines in a few areas (e.g., data entry). Thus, their work provided relatively little guidance for the development of the SDT.

3.3.3 Summary of Implications for SDT

As a result of the review of literature related to human-computer interactions, two general guidelines were identified and subsequently implemented in the SDT.

First, in selecting the type of dialogue which to be implemented in the SDT, it was clear that some form of computer-initiated dialogue should be utilized given the types of uninitiated users who could be expected to employ the SDT. As a result, three computer-initiated dialogue types -- question and answer, form-filling and menu selection were selected for inclusion in the SDT.

Second, coding of information on the SDT displays was developed in accordance with the most current guidelines in Smith (1979), Sidorsky and Parrish (1980), and Ramsey and Atwood (1980) (see Table 3-17). However, only coding schemes which could be implemented on the Apple III were utilized (i.e., underlining, italics, character size control, position displacement, and arrowing).

Table 3-17

SIDORSKY'S AND PARRISH'S SCHEME FOR HIGHLIGHTING INFORMATION

Highlighting Method	Methods Applicable to SDT
Brightness Control	
Character Size Control	x
All Upper Case	x
Reverse Display	
Underlining	x
Different Font	
Color Control	
Blinking, Pulsating	
Boxing	x
Arrowing	x
Symbolic Tagging	
Alphanumeric Tagging	
Position Displacement	

3.4 DEVELOP SDT

An overview of the process used to develop the SDT is presented inn Figure 3-2. More details on the steps in this process are provided in the sections which follow.

3.4.1 Identify SDT Requirements

Detailed functional requirements were developed describing (1) the types of data elements which should be included in the SDT, (2) the types of human-computer dialogue techniques to be used in the SDT, (3) the estimated size and scope of the SDT, and (4) the type of communication which could be expected between the microcomputer and mainframe in the SDT. Input for the development of these requirements was provided by (1) the review of LSCMM documents and processes, particularly the output reports generated by these processes which are listed in Table 2-4 (see Section 2.1), (2) the interviews with acquisition participants (see Section 2.2), (3) the review of data base management techniques and capabilities (see Section 3.2), and (4) the review of human computer interaction guidelines (see Section 3.3).
The detailed SDT requirements were listed in the first yearly report of the ETES development contract.

3.4.2 Identify Data Elements

A detailed data dictionary was developed describing (1) the title of each data element, (2) the maximum length of the data element, (3) the maximum number of the data elements, (4) the type of data contained element (alphanumeric or

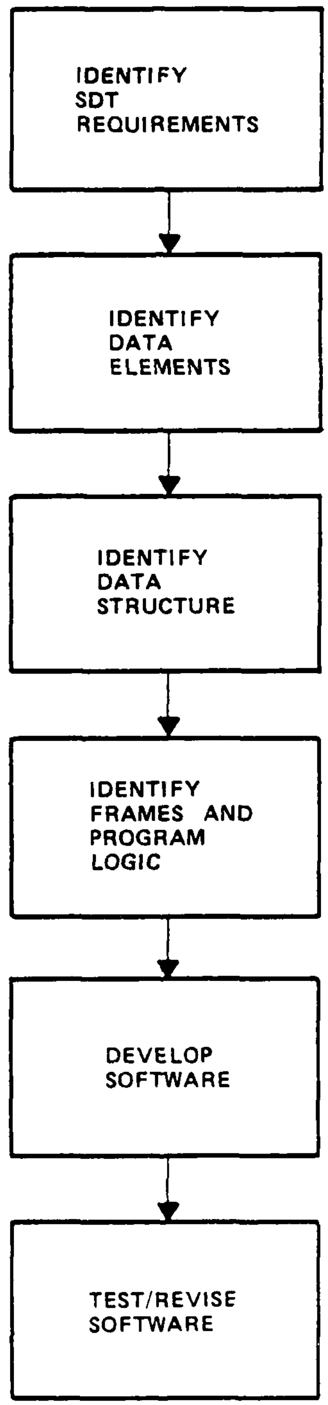

Figure 3-2 Overview of Process Used to Develop SDT

numeric, (5) the category of the data element (entity, subentity, and attribute) (6) the relationships between other elements in the data structure and, (7) the definition to be used to describe the data elements.

The data dictionary was automated to facilitate update. The final version of the data dictionary is listed in Appendix A of the SDT User's Guide. An example page from the data dictionary is presented in Table 3-18.

3.4.3 Identify Data Structure

Concurrent with the identification of data elements, the SDT data structure was identified. The data structure specifies what data elements are entities, subentities, and attributes (see Section 1 for a description of these concepts). Seven major entities were identified: functions, missions, tasks, equipments, duty positions (personnel), media, and courses. Figure 3-3 describes the data structure that was used to describe the relationships between these entities. A more detailed description of the SDT data structure is provided in Appendix A of the SDT User's Guide. As Figure 3-3, indicates, the SDT employs a hierarchical data structure (see Date 1971 for a description of different data base structures). Originally, the intent was to use a n n-hierarchical or relational data base structure which would allow each entity to be associated with each of the other entities. However, the relational data base structure required internal memory requirements that were beyond that which were available on a microcomputer.

Table 3-18 Example of SDT Data Dictionary Page

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Entity Name          Nb. Type         Glossary Definition...
------               ---------        ----------------------

Course Costs         32 Single Sub    COURSE COSTS-  Costs associated with the Course.
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

Course Costs Attribute                Glossary Definition...
----------------------                ----------------------

 1) INSTRUCTIONAL DEPT (OMA)          INSTRUCTIONAL DEPT (OMA) COST-  Operation and Maintenance, Army (OMA) cost of
          Decimal Value                                               the academic departments;  this includes pay
          width=8 places=2                                            and allowances of instructors and academic
                                                                      department staff, consumable supplies and
                                                                      equipment, and contractual services.
                                                                      7 digits, 2 decimal places

 2) INSTRUCTIONAL DEPT (MPA)          INSTRUCTIONAL DEPT (MPA) COST-  Military personnel, Army (MPA) cost of the
          Decimal Value                                               academic departments;  this includes pay and
          width=8 places=2                                            allowances of instructors and academic depart-
                                                                      ment staff, consumable supplies and equipment,
                                                                      and contractual services.
                                                                      7 digits, 2 decimal places

 3) FLYING HOUR COST/STUDENT          FLYING HOUR COST PER STUDENT-  Operation and Maintenance, Army (OMA) and
          Decimal Value                                              Military Personnel, Army (MPA) costs of flying
          width=8 places=2                                           hour instruction.
                                                                     7 digits, 2 decimal places

 4) DIRECT MISSION OTHER(OMA)         DIRECT MISSION OTHER (OMA) COST-  Operation and Maintenance, Army (OMA) school
          Decimal Value                                                 overhead costs such as commandant, office of
          width=8 places=2                                              the secretary, director of logistics, director
                                                                        of support, director of evaluation, school
                                                                        brigade, etc.
                                                                        7 digits, 2 decimal places

 5) DIRECT MISSION OTHER(MPA)         DIRECT MISSION OTHER (MPA) COST-  Military Personnel, Army (MPA) school over-
          Decimal Value                                                 head costs such as commandant, office of the
          width=8 places=2                                              secretary, director of logistics, director of
                                                                        support, director of evaluation, school
                                                                        brigade, etc.
                                                                        7 digits, 2 decimal places
```

- Percent performing - The greater the proportion of individuals in an MOS who perform a task on the job, the greater the payoff for training them in an institution. Thus, if a specific duty position accounts for a substantial percentage of the personnel within an MOS, then that duty position is identified to be trained in the institution. For example, for MOS 95B, Military Police, at Skill Level 1, there are several different duty positions, such as military police, desk clerk, radio dispatch clerk, fingerprint clerk, machine-gunner, investigator, prisoner-of-war processing specialist, etc. The majority of these duty positions account for a relatively small percent of the total MOS strength. However, the training assignment decision is easy because the position of military police accounts for approximately 60 percent of the MOS for Skill Level 1.

- Time between training and required job performance - If a task is complex and requires practice to maintain proficiency then tasks which are not performed by soldiers within 6 months after training should be trained in the unit.

- Consequences of Inadequate Performance - This criteria is important insofar as it indicates which tasks may need concentrated or professional instruction that can best be accomplished in an institutional setting.

Data on these or other selected criteria can either be collected in surveys conducted directly by the analyst or

through the Army Occupational Survey Program (AOSP) (more details on procedures for collecting this data are provided in Section 3.1.) These data can be summarized on a worksheet like that shown in Table 3-10. Data entries to this worksheet should consist of mean scores/ratings for each task on each criteria.

As part of the data collection process, the user should also examine the Trainer's Guide for the MOS. This guide will define the specific training settings currently used for the MOS. If a new MOS is involved, training settings for other comparable MOSs should be used (see Section 2.0 for information on identifying comparable MOSs).

3.2.2.3 Make Training Setting Assignments

Training setting assignments must be made in a two step process. First, tasks should be assigned to the either institutional or unit training setting categories. Second, specific settings within each of these general categories must be determined. It should be noted that within the institutional training setting category, there is a close correspondence between specific training settings and skill level. Thus, if you know the skill level of a task and have made the assignment to the institutional training category the assignment of tasks to specific institutional training settings is largely determined. Listed below are the relationships between skill level and institutional training settings.

- Skill Level 1 - Basic Training, Advanced Individual Training (AIT), or One Station Unit Training (OSUT).

SDT MODE SELECTION

SELECT SDT OPERATION MODE:

-EXIT SDT-	(Terminate the Program)
-AUDIT/UPDATE-	(Examine Audit Trail/Update on Honeywell at DRC)
-INPUT DATA-	(Add Tabular Data into the SDT data files)
-CORRECT DATA-	(Change Specific Attribute for a Particular Entity)
-OUTPUT DATA-	(Display or Print Existing Data)
-SAVE/RESTORE-	(Copy this system to or from diskette)
-APPLICATIONS-	(Execute the Applications Programs)
-AUXILIARY-	(Execute Auxiliary SDT Programs)

Figure 3-4 Example of SDT Menu

Software Documentation. This documentation provides a general description of the SDT programs, and subroutines , library functions and program logic.

3.5 APPLY SDT TO ARMY WEAPON SYSTEM

The original objective of this task was to validate the SDT through a "simulated system development exercise." Recognizing the limited relevancy associated with such an exercise, an attempt was made to apply the SDT to a "real" Army weapon system development project. With this in mind, an extended set of discussions was held with the Ballistics Missile Defense (BMD) office regarding the possible application of the SDT and other ETES tools to the manned BMD subsystems. Initial talks with this office were extremely positive and provisions of significant additional funds to expand the ETES application seemed likely. However, the BMD office finally decided that an ETES application would not be appropriate since (a) the BMD system concept had been changing radically and had not yet been approved by Congress, and (b) existing data on the system was considered "sensitive" and not appropriate for release to outside contractors.

The long yet unproductive discussions with the BMD office when coupled with the tight ETES development schedule, make it impossible to attempt to develop another extensive application of the SDT. Instead, it was decided to examine the SDT in a limited application to the Single Channel Ground Activiated Radar System (SINCGARS). Since a HARDMAN methodology was being conducted on SINCGARS by the same

contractor who was developing the SDT (DRC), SINCGARS offered a low cost and rapid means of applying the SDT.

During the SINCGARS application, the SDT was used to describe system functional requirements, tasks, and equipments. Three criteria were used to assess the validity of the SDT during this application: ease of use, adequacy of SDT as a Data Base Management tool, and meaningfulness of results. Ease of use was assessed by interviewing the personnel who applied the SDT. Meaningfulness of results and data base adequacy was assessed by examining the data input into the SDT. The results of the interviews indicated that the SDT was easy to use and that it could adequately perform the data base functions of storing, updating, and outputting system data. The major user of the SDT was a former Army training analyst who was able to obtain meaningful output for an SDT entity within one week of his initial session on the computer; - this despite the fact that he was provided with no user guide; (the user's guide was developed in a later task), and with only a twenty minute briefing on SDT operation.

However, meaningfulness of the results produced during the application appeared to be only fair. More specifically, there appeared to be some confusion regarding the meaning and use of several of the non-training related SDT data elements, such as system functions and missions. This problem seems reasonable since the ETES user guides did not exist and there were no other documents describing the use of several of these non-training related data elements.

In summary, the results of the SDT application clearly indicated that (1) the SDT was indeed easy to use and (2)

successful usage of the SDT and all its associated data elements would require users to either be familiar with ETES procedures which generate the SDT data elements or to have the user's guides for these procedures on-hand for reference throughout the application of the SDT.

SECTION 4 - TASK 3: DEVELOP TRAINING ESTIMATION AIDS AND PROCEDURES

Figure 4-1 displays the procedures that were used to develop the Training Estimation Aids and Procedures. More details on each of these steps are described in the sections which follow.

4.1 IDENTIFY FUNCTIONAL REQUIREMENTS

Based upon the analysis of LCSMM requirements and user needs which was conducted in Task 1, a detailed listing of the functions which a comprehensive set of early training estimation aids and procedures must achieve was identified. This list is presented in Table 4-1. The original intent of Task 4, as outlined in the statement of work, was to simply develop aids and procedures for generating task descriptions. However, the results of the Task 1 review of existing Army procedures indicated that an early training estimation must perform six basic functions. These functions are:

(1) Estimate and describe a complete list of system functions. Without a complete list of system functions and associated performance goals it is extremely difficult to build a comprehensive system description or to evaluate how well the description meets requirements. Functional

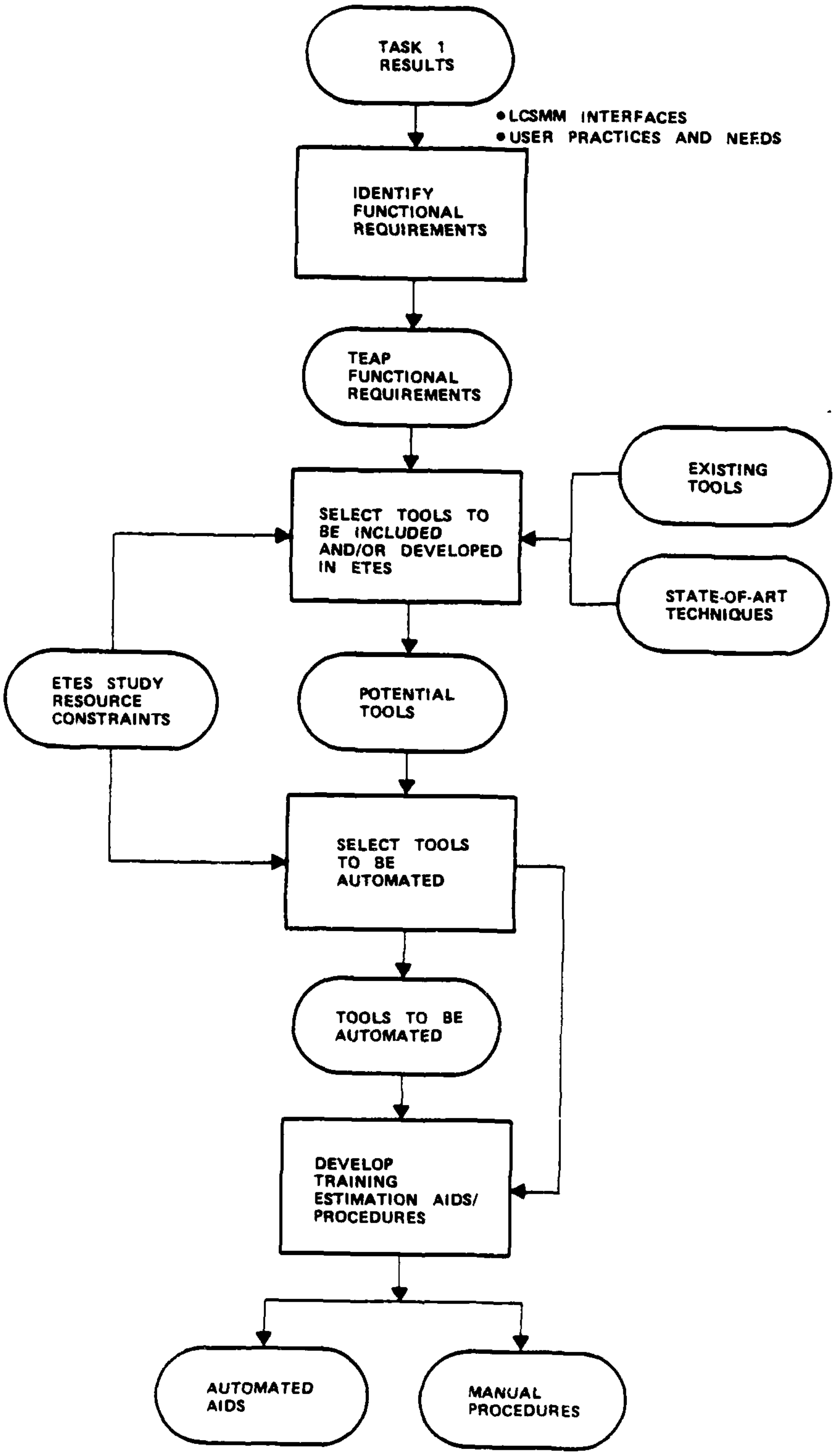

Figure 4-1 Procedures for Developing Automated Training Estimation Aids/Procedures

Table 4-1 FUNCTIONAL REQUIREMENTS FOR TRAINING ESTIMATION AIDS/PROCEDURES

Functions Selected for Inclusion in Training Estimation Aids/Procedures

FUNCTION	NEW OR EXISTING TOOL	TYPE OF MODIFICATION (IF EXISTING)	COMMENTS
1.0 Conduct Function Requirements Analysis	-	-	
1.1 Identify Required System Functions	New		ETES procedures subsequently applied in HARDMAN studies
1.2 Identify Performance Measures and Goals	New		"
1.3 Allocate Required System Functions & Identify Lower Level Functions	New		"
1.4 Establish Baseline Comparison System	HARDMAN	Extensive Proceduralization and Refinement of Existing HARDMAN Procedures.	
1.5 Identify Required System Improvements/New Technologies	HARDMAN	"	
1.6 Format New System Design	HARDMAN	"	
2.0 Generate Tasks	-	-	
2.1 Identify, Collect, Format Data	New		
2.2 Develop BCS Tasks	New		
2.3 Assign BCS Tasks to MOS, Duty Position and Skill Level	HARDMAN	Extensive Proceduralization of HARDMAN Procedures	

Table 4-1 (Continued..)

Functions Selected for Inclusion in Training Estimation Aids/Procedures

FUNCTION	NEW OR EXISTING TOOL	TYPE OF MODIFICATION (IF EXISTING)	COMMENTS
2.4 Develop New System Task List	New		
2.5 Assign New System Tasks to MOS Duty Position, and Skill Level	HARDMAN	Extensive Proceduralization of HARDMAN Procedures	More Refined Procedures being developed in ARMPREP.
3.0 Estimate Training Program	-	-	
3.1 Select Tasks for Training	Job and Task Anal. Handbook	Minor Modifications to Existing Procedures	
3.2 Assign Tasks To Training Settings	New	-	
3.3 Identify Skills and Knowledges	Existing ISD Procedures	Extensive Modifications to Deal with Data Problems Associated with Early Phases	
3.4 Develop Target Population Description	Job and Task Anal. Handbook	Minor Modifications. Specifications of Input Data for Job and Task Analysis Handbook Procedures.	
3.5 Sequence Tasks/Skills for Training	New	-	
3.6 Construct Quasi-Program of Instructions	HARDMAN	Extensive Modification. Significant Proceduralization of HARDMAN Techniques	
3.7 Assign Task/Skills to Media	TEEM	Extensive Modification. Media Assignments Conceptualized as Dynamic Prog. Problem.	Automated in Media Selection Program
3.8 Construct Training Paths	HARDMAN	Extensive Modification. General HARDMAN Concept Tailored for Army	
4.0 Estimate Training Resources	-		

Table 4-1 (Continued..)
Functions Selected for Inclusion in Training Estimation Aids/Procedures

	FUNCTION	NEW OR EXISTING TOOL	TYPE OF MODIFICATION (IF EXISTING)	COMMENTS
4.1	Develop Course Operating and Support Plan	New	-	
4.2	Determine Number of Students to be Trained	HARDMAN	Extensive Modification. Basic HARDMAN Concept used to Develop Army Algorithms	
4.3	Determine Instructor Requirements	New	-	
4.4	Determine Facilities Requirements	New		
4.5	Determine Training Device/ Equipment Requirements	New		
4.6	Determine Requirements for Other Resources	New		
5.0	Determine Training Cost	-	-	
5.1	Estimate Individual Course Costs	HARDMAN	Extensive Modification. General HARDMAN Concepts Tailored for Army	Automated in Resource and Cost Estimation Technique
5.2	Aggregate Course Costs	HARDMAN	Minor Modifications.	
6.0	Estimate Training Efficiency/ Effectiveness		-	
6.1	Estimate Training Efficiency	TEEM	General Concept Developed in TEEM extended to Other Training Program Elements	Automated in Media Selection Program
6.2	Estimate Training Effectiveness	Rembass Study	REMBASS Procedures Simplified to Reduce Data Input Demands	Provides Crude Estimate of Effectiveness.

Table 4-1 (Continued..)

Functions Not Selected for Inclusion in Training Estimation Aids/Procedures

FUNCTION	REASON WHY NOT SELECTED
• Estimate Collective Training Requirements	-
- Generate Collective Tasks	
- Estimate Training Programs	Lack of Resources
- Estimate Training Resources	Lack of Resources
- Estimate Training Cost (O&S)	Lack of Resources
- Estimate Training Efficiency/Effectiveness	Lack of Resources
• Estimate Unit Training Requirements	
- Estimate Training Programs	Lack of Resources
- Estimate Training Resources	Lack of Resources
- Estimate Training Costs (O&S)	Lack of Resources
- Estimate Training Efficiency/Effectiveness	Lack of Resources
• Provide Training Input to Operation Testing	-
- Provide Input to Test Plan Development	Covered in HRTES
- Assess Results of Training	Covered in HRTES
• Estimate Acquisition Training Costs	Lack of Resources
• Develop Detailed Training Efficiency/ Effectiveness Measures	Lack of Resources

information items are identified as part of the QPOI construction process (Procedure 3.6), identification of course locations is relatively straightforward. Additional guidance for course location identification can be provided by examining (a) the course locations used in comparable existing courses and (b) the projected locations where the weapon system will be fielded.

4.1.2 Determine Course Frequency

Course frequency (i.e., the number of starts and sessions per site) is determined by applying the algorithm listed in Table 4-1. To estimate course frequency, you must determine the number of students to be trained (Procedure 4.2). The algorithm listed in Table 4-1 must be applied for each location and year in which the course will be given.

4.1.3 Determine Usage Rates

Usage rates are determined for instructors and training media. The usage rate for instructors is called the student/instructor ratio. The usage rate for media is called the student/media ratio.

Student/instructor ratios are determined for each instructional method used in a course. Table 4-2 displays the student/instructor ratios that are provided for each type of instructional method in DA Pam 570-558 and TRADOC Cir 351-12.

Student/media rates are determined by identifying the rates that were used for similar types of media in comparable courses. This information may be obtained by examining the

TABLE 4-1. ALGORITHM FOR DETERMINING NUMBER OF COURSE STARTS AND SESSIONS PER SITE.

1. Establish number of courses required per site

$$\left(\frac{\text{STUDIN}}{\text{NSITE}}\right) \div \text{NMAX} = \text{NCOURSE}$$

STUDIN	=	Student Input Requirements
NSITE	=	Number of Training Sites
NMAX	=	Maximum Student-Instructor Ratio for Course
NCOURSE	=	Number of Courses Required Per Site

2. Determine maximum number of starts per year (CMAX)

$$\frac{50}{\text{CLENGTH}} = \text{CMAX}$$

CLENGTH	=	Course Length in weeks
CMAX	=	Maximum Number of Course Starts per year (NCON)

3. Select the smaller of NCOURSE or CMAX as the number of course starts (NCON) required per site.

4. Determine maximum number of sessions needed per start (NSES)

If NCOURSE   CMAX, NSES = 1

If NCOURSE   CMAX, $\frac{\text{NCOURSE}}{\text{MAX}}$ = NSES

Round NSES up to next highest unit.

between the Army HARDMAN applications and ETES. ETES procedures for determining system functional requirements, estimating training programs and estimating training resources and costs were incorporated into HARDMAN. In many cases, since HARDMAN was being continuously applied to Army systems during ETES development ETES developed procedures were applied in Army HARDMAN applications before these procedures were fully completed and integrated in ETES.

TEEM provided two critical inputs to ETES. First, it provided a media selection model, which with significant modifications, provided an effective vehicle for early media selection (see the description of the ETES Media Selection Program in Appendix A). Second, the TEEM concept of training efficiency provided a useful, albeit crude measure for estimating the "effectiveness" or goodness of an early concept for a training program element. More specifically, in the training efficiency concept, the goodness of a training program element (such as media) is measured by assessing how well the characteristics of the tasks to be trained match the characteristics of the training program element.

After existing tools were selected for inclusion in the training estimation aids and procedures, the functions were examined to identify the areas where state of the art technology could be most effectively applied to develop new tools. In determining whether a new tool was appropriate, three factors were considered: (a) the criticality of the function to early training estimation, (b) the technical feasibility of developing the new tool/given the current state of the art, and (c) the resources available under the

ETES contract. Table 4-1 lists the functional areas where new tools were developed.

There were five major functional areas where state-of-the-art technology and resource constraints prohibited the development of a new training estimation aids and/or procedure. First, it was not possible to develop techniques for estimating collective training. Second, it was not possible to develop procedures for estimating unit training. Thus, the ETES Training Estimation Aids and Procedures developed in this contract focused on individual institutional training (see Table 4-2). It was decided that it was more beneficial to develop a complete set of procedures for dealing with individual institutional training which covered the entire training estimation process from task enumeration to training program evaluation than to develop a partial set of procedures for the full range of Army training settings. Third, procedures were not developed for estimating acquisition costs for training programs (thus, only procedures for estimating operations and support costs were developed). The major reason for this was that it was extremely difficult to obtain any kind of systematic data on training acquisition costs. More specifically, it was very difficult to obtain any kind of useful data for existing training programs. It was determined that while some data on acquisition costs is available in informal data bases throughout the Army, the cost of locating and analyzing this data would have expended too much of available ETES development resources.

Fourth, procedures were not developed for providing input data to, or evaluating the results from, Operational Testing (OT) even though these functions were clearly related to

Table 4-2 Focus of Current ETES Training Estimation Aids/Procedures

	Institutional Training	Unit Training
Individual Training	X	
Collective Training		

X = Current Focus

training estimation during the Demonstration and Validation phase of the acquisition process. The reason for this was that a separate project, the Human Resource and Test Evaluation System (HRTES), was designed to provide procedures for providing manpower, personnel and training related input into Operational Testing (OT). However, guidelines were developed for providing input to HRTES. HRTES and ETES and other manpower, personnel and training tools are being integrated in the MIST contract. (see Appendix D for a description of HRTES and MIST).

Fifth, while procedures were developed for estimating training efficiency/effectiveness, development of a complete capability for estimating early effectiveness was not possible. More specifically, it was not possible to develop measures of effectiveness that were appropriate for inclusion in cost/benefit ratios. Such ratios require the development of effectiveness criteria which can be measured on a true ratio scale. It was not possible to develop procedures which could produce effectiveness measures which met all the theoretical requirements for ratio scale development.

4.3 SELECT TOOLS TO BE AUTOMATED

Once potential tools were identified, an analysis was conducted to identify which tools should be automated. Each tool which was amenable to automation was identified and assigned a priority, the intent being to automate tools based on their priority until funds allotted for this task were expended (No specific set of procedures were mentioned in the statement of work). Priority was based on three

factors (a) how critical the tool was to early training estimation, (b) the amount of training analyst time that would be expected to be saved by automating the tools and (c) ease with which the tool could be automated, given the hardware/ software configuration selected for the SDT (Apple III/PASCAL). The overall goal in operating the tools was to get the "biggest bang for the buck" while recognizing that additional automation would take place in the ETES implementation contract.

Two automated tools were developed; one for assigning tasks to media based on efficiency of the training media and one for estimating operating and support costs for institutional training courses. An overview of these two tools is provided in Appendices A and B. A more detailed description of these two automated tools is provided in the User's Guide Media Selection Program and User's Guide: Automated Resource and Cost Estimation Technique.

4.4 DEVELOP TRAINING ESTIMATION AIDS AND PROCEDURES

Manual and automated training estimation aids and procedures for the functional areas selected in the previous subtasks were developed. The two automated aids were developed using the procedures outlined in Figure 4-2. A description of the Training Estimation Aids and Procedures which were developed under this subtask is provided in Section 1.5.2.

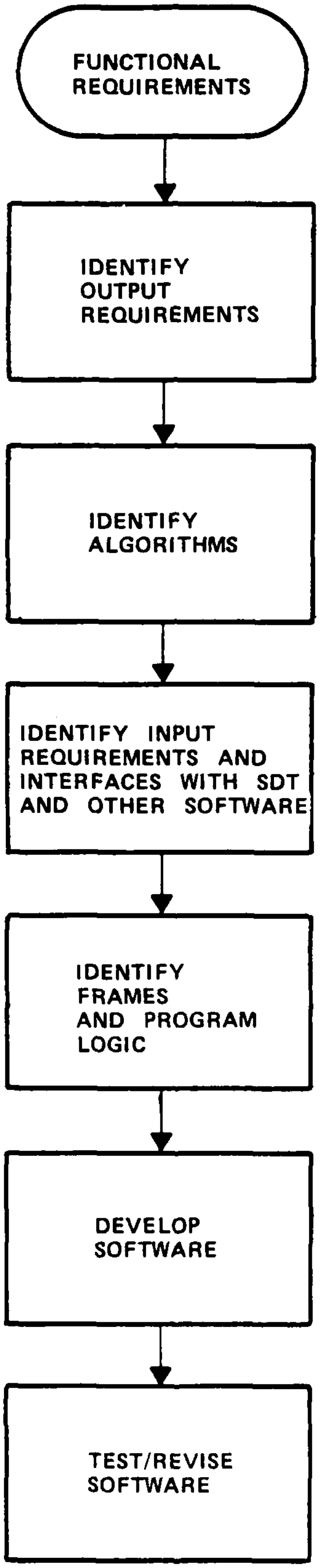

Figure 4-2 Procedures for Developing Automated Training Estimation Aids/Procedures

SECTION 5 - TASK 4: DEVELOP EVALUATIVE TECHNOLOGY

Two major activities were accomplished under this task. First, a review was conducted of existing simulation techniques to determine if any of these techniques could be used in early training estimation. Second, the Evaluative Technology component of ETES was constructed. More details on these two activities are presented in the sections which follow.

5.1 REVIEW/EXAMINE SIMULATION TECHNIQUES

A detailed review was made of existing simulation techniques to determine if any of these techniques had applicability for early training estimation.

The purpose of this review was to examine "low cost methods for simulating interacting tasks together with combat scenarios." Ideally, the simulation technique would receive as input system descriptions from the SDT and produce as outputs a listing of the criticality of each human task to overall system performance. Thus, the simulation technique would have the capability of relating both system design concepts and training program concepts to task performance and relating task performance to overall system performance.

Table 5-1 lists the simulation techniques which were reviewed during this task. The two most promising techniques identified during this review were the Systems Analysis of Integrated Networks of Tasks (SAINT) developed

Table 5-1 Simulation Techniques Reviewed During Task 4

MODEL	DEVELOPER	SPONSORING ORGANIZATION
Advanced Continuos Simulation Language	Mitchell and Gautier (1975)	—
NETMAN	Siegel, Lehy, and Wolf (1977)	Army Research Institute
Systems Analysis of Integrated Network of Tasks (SAINT)	Pritsker, Wortman, Seum, Chubb, and Seifert (1974)	Aerospace Medical Research Lab
Technique for Human Error Prediction (THERP)	Swain and Gutman (1975)	—
Human Operator Simulator (HOS)	Strieb (1975)	Naval Air Development Center

by Pritsker and Human Operator Simulation (HOS) Technique developed by Streob, Glenn and Whery (1978). However, an examination of these two techniques indicated that they both required detailed task data as input. This type of detailed task data is generally not available during the early phases of the acquisition process. Consideration was given to modifying one of these techniques, SAINT, to accept more generalized task input. However, this approach was not taken for two reasons. First, advanced development work on a human operator simulation using SAINT was being conducted in ARI's MOPADs contract. It was felt that this work would make previous SAINT work obsolete and that it made more sense to wait until this more advanced MOPADs simulation model was complete and then modify this model for early simulation purposes than to modify a more primitive SAINT model. Second, and most importantly, the review of existing Army early training estimation needs conducted during Task 1 indicated that there were more real and pressing needs for evaluating early training programs with respect to other key criteria such as resource requirements, cost, and training efficiency/effectiveness than there were to evaluate these programs with respect to task criticality (several less sophisticated procedures for estimating task criticality were readily available and were eventually incorporated into the ETES Training Estimation Aids and Procedures).

5.2 DEVELOP EVALUATIVE TECHNOLOGY

An overview of the procedures that were used to develop the Evaluative Technology is provided in Figure 5-1. A more detailed description of these procedures is provided in the section which follows.

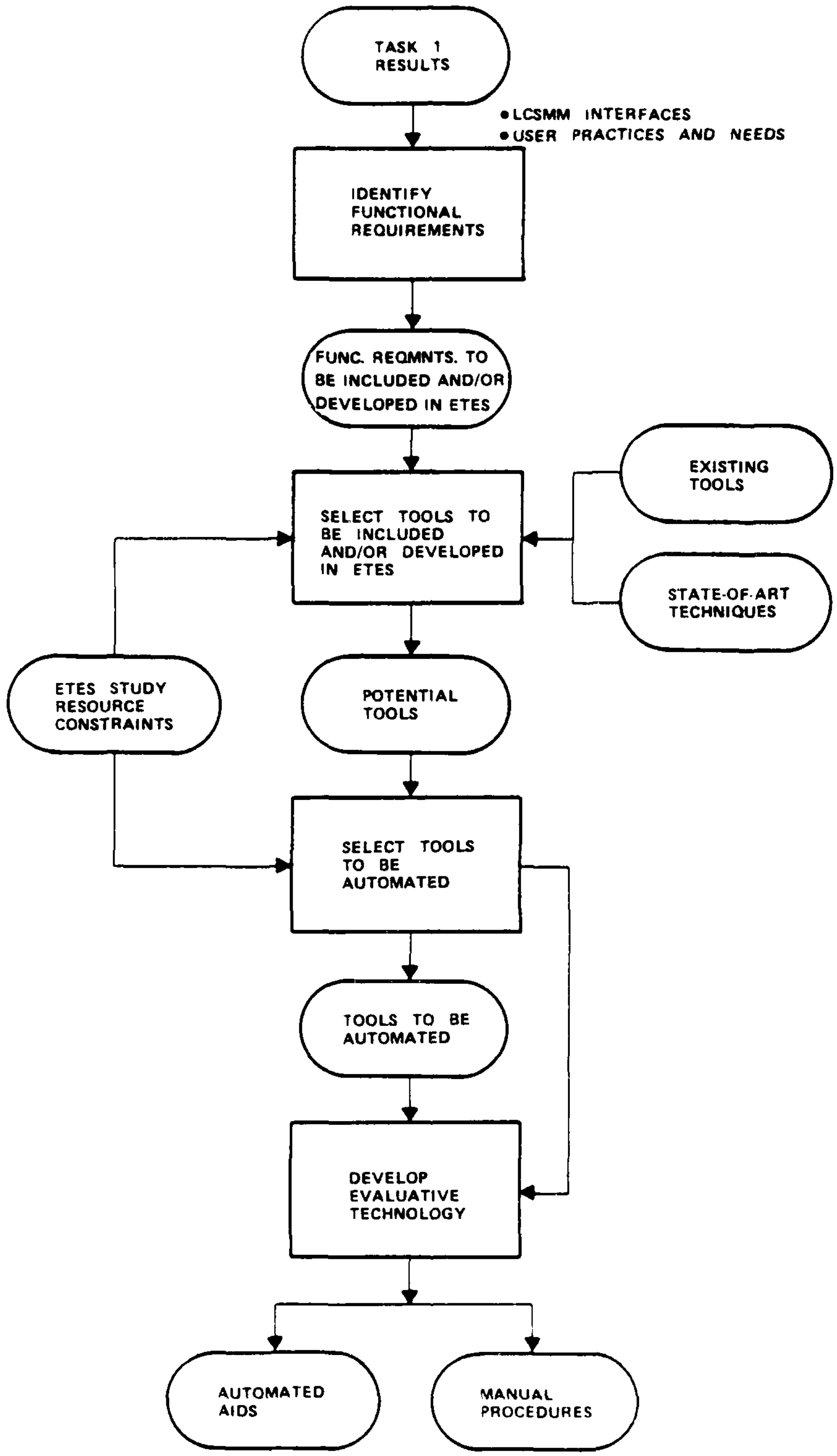

Figure 5-1 Procedures for Developing Evaluative Technology

5.2.1 Identify Functional Requirements

Based upon the analysis of LCSMM requirements and user needs identified in Task 1, it was determined that an effective Evaluative Technology for evaluating early training programs must contain procedures for (1) developing figures-of-merit for assessing the integrated impacts of the training requirements developed in the Training Estimation Aids/Procedures, (2) identifying potential problem areas for system training and the likely sources of these problems, (3) identifying/evaluating training alternatives, which can be expected to reduce the training problems, (4) developing training-related input to key acquisition documents, and (5) determining/evaluating training development schedules (see Figure 5-2)

5.2.2 Identify Functions and Tools to be Included in Evaluative Technology

Once the functions required for evaluating early training programs were identified, existing tools and technologies were examined to (1) identify any existing tools which could be modified to meet the early training evaluation functions, and (2) identify the most promising areas for new development.

In order to be selected for inclusion in ETES, a tool had to meet two general requirements. First, it had to be capable of producing or being modified to produce output that was appropriate for the early training of the acquisition process. Second, the tool had to be capable of being applied with the types of general data and information that

are available during the early phases of the acquisition process.

Table 5-2 lists the tools which met the criteria for inclusion in the Evaluative Technology.

After existing tools were investigated, the functions were examined to identify the areas where state-of-the-art technology could be effectively applied to develop the new tools. In determining whether a new tool was feasible, three factors were considered: (a) the criticality of the function to early training estimation, (b) the technical feasibility of developing the new tool given the current state-of-the-art, and (c) the resources available under the ETES contract. Table 5-2 lists the functional areas where new tools were developed.

As Table 5-2 indicates, it was possible to develop a tool for each of the functional areas related to training evaluation. However, in two of the functional areas it was not possible to develop tools which fully met all requirements associated with these functions.

First, in the functional area involving the development of figures-of-merit, procedures were identified for developing estimates for eight figures-of-merit (training cost, training efficiency, training effectiveness, congruence with training development guidelines, congruence with program requirements, training complexity, training capacity and feasibility of the training program). However, only a very simplified procedure was identified for aggregating these scores. There are several more sophisticated techniques such as multiattribute utility analysis which could be used

Table 5-2 FUNCTIONAL REQUIREMENTS FOR EVALUATIVE TECHNOLOGY

Functions Selected for Inclusion in Evaluative Technology

FUNCTION	NEW OR EXISTING TOOL	TYPE OF MODIFICATION (IF EXISTING)	COMMENTS
7.0 Evaluate Training Program	-	-	-
7.1 Identify/Construct Figures-of-Merit	-	-	-
7.1.1 Identify Costs	HARDMAN	Extensive Modifications, General HARDMAN Concepts Tailored for Army	Automated in Resource & Cost Estimation Technique.
7.1.2 Identify Efficiency	TEEM	Gen. Concept Developed in TEEM for Media Extended to Other Training Program Elements	Automated in Media Selection Program
7.1.3 Identify Effectiveness	Rembass Study	REMBASS Procedures Simplified to Reduce Data Input Demands	Provides Crude Estimates of Effectiveness
7.1.4 Determine Congruence with Training Guidelines	New	-	
7.1.5 Determine Congruence with Program Reqs.	New	-	
7.1.6 Estimate Training Complexity	New	-	
7.1.7 Estimate Feasibility	New	-	
7.1.8 Construct Summary Score	New	-	Only Crude Capability Provided in Current ETES
7.2 Identify Likely Problem Areas	New	-	
7.3 Identify Likely Causes	New	-	Only Crude Capability Provided in Current ETES
7.4 Identify Alternatives	New	-	

Table 5-2 (Continued..)

Functions Selected for Inclusion in Evaluative Technology

FUNCTION	NEW OR EXISTING TOOL	TYPE OF MODIFICATION (IF EXISTING)	COMMENTS
7.5 Evaluate Alternatives	New	-	
7.6 Assess Impact of System Changes	New	-	
8.0 Develop Input to Acquisition Processes	-	-	-
8.1 Develop/Monitor Training Development Schedule	New		Automated with Visi-Schedule Software
8.2 Develop Inputs to Acquisition Processes and Documents	New		Interfaces Other ETES Procedures with Acquisition Process

Functions Not Selected For Inclusion In Evaluative Technology

FUNCTION	REASON WHY NOT SELECTED
• Estimate Impact of Training Concept on System Performance	Lack of Resources
• Assess Integrated Impacts of Manpower, Personnel and Training	Not Within Scope of Study

to aggregate these scores but these techniques require more sophisticated subjective estimation methods. Modification of such methods for use during the early phases of the acquisition process was not feasible within the resource constraints of the ETES development contract.

Also within the same functional area of developing training figures-of-merit, it was not possible to develop a figure-of merit which would provide a measure of the expected impact of the training concept on system performance. During the early phases of the acquisition process, the only way to develop such a measure is to use a simulation model. As section 5.1 indicated, development of such a model was not possible within the resource constraints of the ETES development contract.

Finally, it was only possible to develop crude procedures for identifying the likely causes of training problems. Development of more sophisticated procedures required the development of a quantitative model (preferably a simulation model) for relating training program elements to the training figures of merit. Again, such a complicated model was beyond the scope of the present ETES development effort.

5.2.3 Select Tools To Be Automated

Once potential tools were identified, an analysis was conducted to identify which tools should be automated. Each tool which was amenable to automation was identified and assigned a priority, the intent being to automate tools based on their priority until funds available for this task were expended. Priority was based on three functions: (a)

how critical the tool was to early training estimation, (b) the amount of time that would be expected to be saved by automating the tool, and (c) the ease with which the tool could be automated given the hardware/software configuration selected for the SDT (Apple III/PASCAL).

Within the resource constraints of the ETES contract, it was only possible to select one additional tool for automation, the Automated Training and Planning and Scheduling Technique (APST). An overview of this program is provided in Appendix C. However, procedures were also identified for using the automated Resource and Cost Estimation Technique developed as part of the ETES Training Estimation Aids/Procedures to conduct sensitivity analysis.

5.2.4 Develop Evaluative Technology

Potential automated aids and procedures which were identified in the previous step were developed. A description of these aids and procedures is provided in Section 1.5.3.

SECTION 6 - TASK 5: DEVELOP USER'S GUIDE

During this task, user's guides were developed for the three ETES components (SDT, Training Estimation Aids and Procedures, and Evaluative Technology) and a final report was constructed to describe the research conducted during the ETES study.

Table 6-1 summarizes the documents developed during this task.

To facilitate independent application of the four automated ETES tools (SDT, Media Selection Program, Automated Resource and Cost Estimation Technique, and Automated Training Planning and Scheduling Technique), separate users' guides were developed for each of these tools. In addition the ETES manual procedures were consolidated in a single user's guide (see Table 6-1). Each of users's guides was designed to provide detailed step-by-step procedures for using the ETES tools.

Table 6-1 ETES Documentation

- Final Report (150 pages)
- ETES Procedural Guide (300 pages)
- User's Guide: System Description Technology (300 pages)
- User's Guide: Media Selection Program (200 pages)
- User's Guide: Resource and Cost Estimation Technique (100 pages)
- User's Guide: Automated Training Planning and Scheduling Technique (100 pages)
- ETES Software Documentation (300 pages)

SECTION 7- POTENTIAL IMPROVEMENTS TO CURRENT ETES CONCEPT

The ETES development study was designed to provide an initial capability for developing early estimates of training requirements. As Sections 3 thru 6 have indicated, resource constraints prohibited the full development of tools in several key areas.

This section briefly describes the areas in which the current ETES can be improved to (1) provide more accurate estimates of training requirements or (2) provide estimates of training requirements in a more timely and cost-effective fashion.

Table 7-1 summarizes the major improvements which may be made to each component of ETES. A more detailed description of these improvements is provided in the sections which follow.

7.1 IMPROVEMENTS TO SYSTEM DESCRIPTION TECHNOLOGY

There are four general areas in which the System Description Technology could be improved. First, the mainframe functions of the SDT should be expanded and refined to provide a full capability for distributed processing of data. These mainframe functions include techniques for (1) storing a centralized copy of the SDT, (2) transmitting and communicating data to various users, (3) providing security for data base access, and (4) keeping an audit trail of

Table 7-1 POTENTIAL IMPROVEMENT AREAS FOR CURRENT ETES

SDT • Expand Main Frame Functions • Improve Searching and Sorting Capabilities • Improve Graphics Capabilities • Expand SDT Data Elements	EVALUATIVE TECHNOLOGY • Develop More Sophisticated Method for Aggregating Individual Figures-of-Merit • Develop More Sophisticated Method for Identifying Causes of Training Problems • Develop Global Automated Worksheet Linking ETES Automated Functions to Facilitate the Assessment of Design Changes • Integrate with ISD and Other Training Technologies Associated with Later Phases of Acquisition Process
Training Estimation Aids/Procedures • Add Procedures for Estimating Collective Tasks, Training Programs, Training Resources and Costs • Add Procedures for Estimating Unit Training Programs, Resources and Costs • Develop Procedures for Developing More Sophisticated Measures of Training Effectiveness • Develop Automated Aids for Following Functions: 3.1 Select Tasks for Training 3.4 Assign Tasks to Training Settings 4.2 Determine Number of Students to be Trained 4.4 Determine Facilities Requirements 4.5 Determine Other Training Resources 5.2 Aggregate Course Costs	General Areas of Improvement • Integrate ETES SDT with MIST Management Information System Features • Develop Comprehensive Tool for Conducting Cost-Benefit Tradeoff Analysis Among Manpower, Personnel and Training • Develop Tool for Assessing Impact of Alternative Training Concepts on System Performance

system changes. The current version of ETES only provides relatively simple capabilities in each of these areas. More sophisticated capabilities were not developed because it was not possible to identify the "mainframe" computer on which the SDT would be implemented. Since the development of the SDT, however, the Army Research Institute (ARI) has selected the VAX 11/780 as the mainframe computer on which the SDT and other components of the ETES will be implemented. With the identification of the mainframe, more sophisticated software can be developed for the SDT mainframe functions.

Second, the current ETES only has limited capabilities for searching and sorting data. To better meet the unique demands of individual users, a more flexible searching and sorting capability should be developed.

Third, more comprehensive graphics capabilities must be added to the SDT. The current SDT can produce reports that contain the the data elements needed in many key acquisition documents. However, it can only output that data in formats that "look like" the acquisition document.

Fourth, the SDT data elements should be expanded to meet the needs of any additional tools which are developed. Currently, for example, as part of the MIST project, the prototype SDT is being expanded to handle the data required to support manpower and personnel estimation tools.

7.2 IMPROVEMENTS TO TRAINING ESTIMATION AIDS/PROCEDURES

There are four general areas in which the ETES Training Estimation Aids/Procedures can be improved. First,

procedures must be developed for estimating collective tasks, collective training programs, collective training resources, collective training costs, and collective training effectiveness. Second, procedures must be developed for estimating training programs, resources and costs for individual unit training. These two improvements will become increasingly important given the current trend toward shifting more and more training to the unit. Third, procedures must be developed for developing more detailed and more accurate measures of training effectiveness. The current ETES procedures only provide crude estimates of training effectiveness. While appropriate for the very earliest phases of the acquisition process, these procedures do not provide the type of detailed data which is needed for the refined training tradeoff analyses which occur in the later phases of the acquisition process.

Fourth, resource constraints prohibited the development of automated aids for several key functions. Automated aids can assist the training analyst in dealing with the frequent design changes which occur during the earliest phases of the acquisition process. Some of the current TEAP functions which are most amenable to automation are:

3.1 Select Tools for Training
3.4 Assign Tasks to Training Settings
4.2 Determine Number of Students to Be Trained
4.4 Determine Facilities Requirements
4.6 Determine Other Training Resources
5.2 Aggregate Course Costs

7.3 IMPROVEMENTS TO EVALUATIVE TECHNOLOGY

These are four general areas where the Evaluative Technology may be improved. First, the current Evaluative Technology only employs some rather simplified techniques for aggregating individual training figures of merit. While simple to use and appropriate for the very earliest phases of the acquisition process, these techniques do not have the accuracy needed for the detailed tradeoff and sensitivity analyses which occur in later phases of the acquisition process. Second, a more sophisticated tool must be developed for identifying the causes of training problems. One possible tool for performing this complex function is a computer simulation model. As noted in Section 6, development of such a model will not be easy since most simulation models have extensive input data requirements. An alternative approach is to use an artificial intelligence technique to build an "expert system" for diagnosing training problems similar to the MYCIN system which was developed to diagnose medical problems (see Winston, 1977 for an overview of MYCIN).

Third, an automated worksheet was developed for estimating selected training resources and course costs. This worksheet makes it very easy to change data and immediately assess impacts. The automated worksheet concept must be expanded to cover other ETES functions and individual automated aids must be linked together to provide a more systematic capability for assessing impacts.

Fourth, procedures must be developed for interfacing ETES with techniques which are used in the later phases of the acquisition process such as instructional system development (ISD).

7.4 GENERAL AREAS OF IMPROVEMENTS

There are three general areas which, although outside the scope of the current ETES concept, could significantly improve the use of ETES products. First, to facilitate the transmission and communication of data, the SDT data base management system must be incorporated into a Management Information System for Army manpower, personnel and training analysts (this will in fact be done in later phases of the MIST project).

Second, a comprehensive tool must be developed for assessing the integrated impacts of manpower, personnel, and training requirements and for conducting integrated tradeoffs among these three closely linked system elements.

Third, a systematic tool must be developed for estimating the impact of the alternative manpower, personnel, and training concepts on overall system performance. To be useful, this tool must not have extensive input data requirements. Otherwise, it will never be used during the earliest phases of the acquisition process, when most major MPT and system design decisions are made.

APPENDIX A: OVERVIEW OF MEDIA SELECTION PROGRAM

This appendix provides a brief overview of the Media Selection Program. A more detailed description is provided in the User's Guide: Media Selection Program. The Media Selection Program is an automated tool for (1) assigning tasks to media and (2) calculating the efficiency and effectiveness of various task-media combinations. The Media Selection Program allows users to assign tasks to media in a manner that maximizes overall efficiency, maximizes overall "effectiveness," or minimizes overall cost.[1] In addition, it allows users to assign tasks to media in a manner that optimizes various combinations of these variables, including an overall "utility" measure which combines either cost and efficiency or cost and effectiveness.

Efficiency, in the Media Selection Program, is determined by comparing the stimulus, response, and feedback characteristic of the tasks to the stimulus, response, and feedback characteristics of potential media. More specifically, a score is calculated which describes the match between media and tasks on these characteristics. Efficiency for each task-media combination is calculated by dividing this score by the maximum match that may be

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[1] The program uses a relative cost and not actual cost to measure the potential cost requirements of media. In addition, the program does not use a measure of "effectiveness" that fits the most common usage of that terms. Rather effectiveness is actually efficiency weighted by task criticality.

achieved for the task. Total efficiency for a set of tasks is the sum of the efficiency score for individual tasks.[2]

"Effectiveness" is calculated by weighting the efficiency of each task by a task criticality score. The task criticality score is a user-defined weighted combination of the eight task factors typically used in selecting tasks for training. These eight factors are task frequency, percent members performing, percent time performing, task delay tolerance, consequences of inadequate performance, task learning difficulty, probability of deficient performance, and time between entry and performance.

A matrix of relative cost values is stored in the program for each major media category. In addition, a built-in set of algorithms is used to produce the utility measure which combines cost with either effectiveness or efficiency.

PROCEDURAL OVERVIEW

The Media Selection Program is an interactive menu-driven system. This means that users do not have to know or use a computer language to run the program. Instead, they can run through the program by selecting options from a series of menus.

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2 This concept of media efficiency was originally developed by Jorgensen (1978) and was incorporated into Training Efficiency Estimation Model (TEEM) described in Jorgensen, Kubula, and Atlas (1981).

An overview of the procedures for using the Media Selection Program is provided in Figure A-1. To begin the procedures, users must rate each task on (1) the psychological variables to be used to assess the match between tasks and media, and (2) the variables to be used to assess task criticality (the latter is only necessary if effectiveness is being calculated). These scores must be then entered into the ETES data base management system, the System Description Technology. When this is completed, users must enter the Applications Program mode in the System Description Technology, and select the Media Selection Program. Once in the Media Selection Program, users must then select criteria to be used in making media assignments. Seven options for selecting criteria are provided: (1) efficiency, (2) "effectiveness" (3) relative cost, (4) cost and efficiency, (5) cost and "effectiveness," (6) a utility measure, combining efficiency and cost, and (7) a utility measure combining "effectiveness" and cost.

Once the criteria have been selected, users must select the tasks to be included in the analysis (only tasks already in the SDT may be selected). Typically, the tasks for single course module will be selected for each analysis. With the analysis criteria identified, the psychological variables to be used in calculating the match between tasks and media must be selected. Users may select from 12 variables assessing stimuls characteristics, six variables assessing response characteristics and four variables assessing feedback characteristics.[3]

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[3] These psychological variables were taken directly from the TEEM Model (Jorgeson, Kubula, and Atlas; 1981)

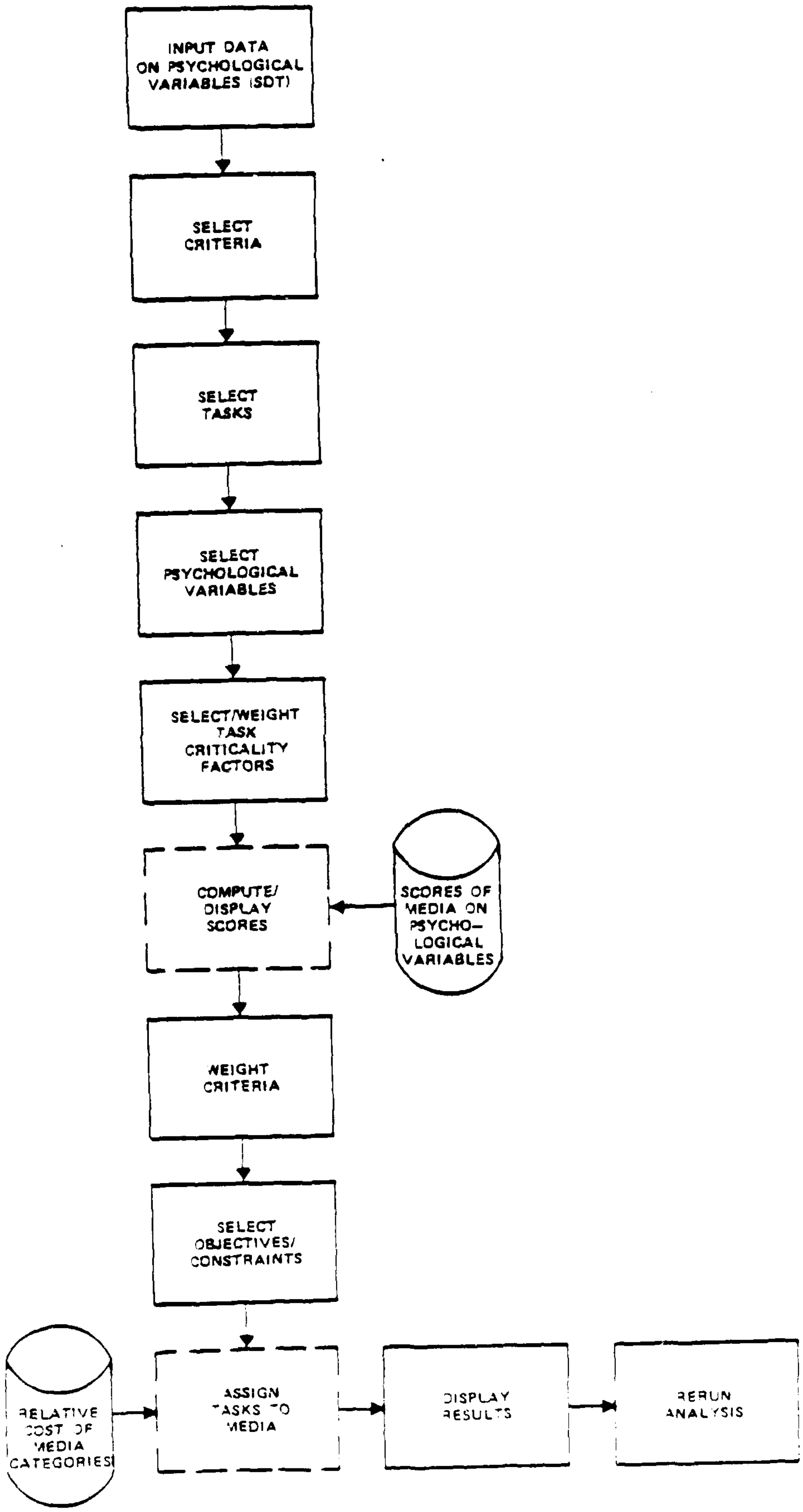

Figure A-1 Overview of Media Selection Program

If the user has selected a set of criteria involving effectiveness (effectiveness, cost and effectiveness, or utility with effectiveness), the weights for the component criticality variables must be entered so that a composite task criticality score can be computed. Eight variables may be used in the calculation of task criticality: (task frequency, percent member performing, percent time performing, task delay tolerance, consequences of inadequate performance, task learning difficulty, probability of deficient performance and time between entry and performance).

At this point, the program has all of the information needed to calculate efficiency and/or effectiveness. It will use this information to calculate the relevant measure and it will display the results.

If the user has selected one of the two utility measures (combining either cost and efficiency or cost and effectiveness) the user will then be required to enter the weights to be used in the computation of utility. Following this, the user must select the objectives and constraints to be used in assigning tasks to media. A listing of the possible combinations of objectives and constraints is displayed in Table A-1. Once this information has been put into the computer, the program will optimally assign the tasks to training media. For instance, if the user selected "maximum effectiveness" as an objective and "minimize cost" as a constraint, the program would determine the assignment of tasks to media which gives the highest overall score on effectiveness and still remains under a user-specified level of overall cost. Once the initial assignments have been examined, the user can examine the effects of several

Table A-1 Possible Assignment Strategies.

OBJECTIVE	CONSTRAINT	ASSIGNMENT STRATEGY	Efficiency	Effectiveness	Efficiency and Cost	Effectiveness and Cost	"Utility" with Efficiency	"Utility" with Effectiveness	Cost	
maximize efficiency	No constraint	Each task is assigned the medium with the greatest efficiency for that task.	X	X	X	X	X	X	X	*
	effectiveness	An assignment of all tasks to media is generated such that total efficiency is maximized and total effectiveness is greater than or equal to user-specified level of effectiveness.		X		X		X		
	"utility"	An assignment of all tasks to media is generated such that total effectiveness is maximized and total "utility" is greater than or equal to a user-specified level of "utility."					X	X		
	cost	An assignment of all tasks to media is generated such that total efficiency is maximized and total cost is less than or equal to a user-specified level of cost.			X	X	X	X		*
maximize effectiveness	no constraint	Each task is assigned the medium with the greatest effectiveness for that task.		X		X		X		*
	efficiency	An assignment of all tasks to media is generated such that total effectiveness is maximized and total efficiency is greater than or equal to a user-specified level of efficiency.		X		X		X		
	"utility"	An assignment of all tasks to media is generated such that total effectiveness is maximized and total "utility" is greater than or equal to a user-specified level of "utility."						X		
	cost	An assignment of all tasks to media is generated such that total effectiveness is maximized and total cost is less than or equal to a user-specified level of cost.				X		X		*
maximize "utility"	no constraint	Each task is assigned the medium with the greatest "utility" for that task.					X	X		*
	efficiency	An assignment of all tasks to media is generated such that total "utility" is maximized and total efficiency is greater than or equal to a user-specified level of efficiency.					X	X		
	effectiveness	An assignment of all tasks to media is generated such that total "utility" is maximized and total effectiveness is greater than or equal to a user-specified level of efficiency.						X		
	cost	An assignment of all tasks to media is generated such that total "utility" is maximized and total cost is less than or equal to a user-specified level of efficiency.					X	X		

Table A-1 Possible Assignment Strategies. (continued)

OBJECTIVE	CONSTRAINT	ASSIGNMENT STRATEGY	Efficiency	Effectiveness	Efficiency and Cost	Effectiveness and Cost	"Utility" with Efficiency	"Utility" with Effectiveness	Cost	
minimize cost	no constraint	Each task is assigned the medium with the least relative cost.			X	X	X	X	X	*
	efficiency	An assignment of all tasks to media is generated such that total cost is minimized and total efficiency is greater than or equal to a user-specified level of efficiency.			X	X	X	X		*
	effectiveness	An assignment of all tasks to media is generated such that total cost is minimized and total effectiveness is greater than or equal to a user-specified level of effectiveness.				X		X		*
	"utility"	An assignment of all tasks to media is generated such that total cost is minimized and total "utility" is greater than or equal to a user-specified level of "utility."					X	X		

*most easily interpreted strategies

alternatives including changes in (1) objective, (2) constraint, (3) criteria, (4) task criticality variables, (5) psychological variables, (6) task criticality variable weights, and/or (7) utility weights.

After users have explored these alternatives, the task-media assignments can be finalized and entered into the SDT.

APPENDIX B: OVERVIEW OF AUTOMATED RESOURCE AND COST ESTIMATION TECHNIQUE

This appendix provides detailed instructions on how to use the Automated Resource and Cost Estimation Technique (RCET). A more detailed description of RCET is contained in the User's Guide: Resource and Cost Estimation Technique. The purpose of RCET is to provide Army Training analysts with an automated tool for estimating instructor requirements and institutional training costs during the earliest phases of the acquisition process.

The Automated Resource and Cost Estimation Technique (RCET) is designed to use input data from the ETES data base management system, the System Description Technology (SDT). Actual calculation of instructors and institutional training course cost in RCET is accomplished by using the VISICALC automated worksheet software developed by Visicorp. The VISICALC worksheet is also used to conduct sensitivity analyses of key parameters.

B.1 CONCEPTUAL OVERVIEW

The Resource and Cost Estimation Technique has three components:

(1) SDT Interface Software - this software is used to select and remove data from the SDT and to format the data for use in the VISICALC program. In addition, it is used to copy the results of the VISICALC program back into the SDT.

(2) Tailored VISICALC Worksheet - this worksheet contains the equations for determining number of instructors and course costs. In addition, it contains all of the commands needed to load and unload the SDT input file, and to conduct sensitivity analyses. This tailored worksheet saves the user from the somewhat tedious process of setting up a VISICALC worksheet and command structure.

(3) Manual Procedures - these procedures describe how to develop input data and how to use the SDT interface software and the tailored VISICALC worksheet.

There are two major products of RCET: (1) a listing of the number of instructors required in the course and (2) a listing of projected costs for the course. An example of the cost elements estimated by RCET is listed in Table B-1. These are the same cost elements used in the Cost Analysis Program of the Army TRADOC Resource Management (ATRM) system.

B.1.1 Calculation of Course Costs

Costs for a new course are estimated by identifying a comparable existing course, obtaining cost data from this course data to reflect the differences in key resource requirements (for example, number of students and number of instructors) between the comparable course and the new course.

This procedure provides estimates of course costs that are (1) empirically based and (2) suitable for the types of high level analyses which are conducted during the early phases of the acquisition process.

Table B-1 Example Cost Elements

PROPOSED COURSE SPREADSHEET

	OMA	MPA	PA	FHMA
DIRECT MISSION				
INSTRUCTIONAL DEPARTMENT	___	___		
FLYING HOUR	___	___		
OTHER	___	___		
SUBTOTAL	___	___		
TROOP SUPPORT				
P8	___	___	___	
P2/3	___	___	___	
AMMUNITION			___	
EQUIPMENT ITEM DEPRECIATION			___	
STUDENT PAY AND ALLOWANCES				
OFFICER		___		
ENLISTED		___		
TRAVEL PAY TO COURSE	___	___		
PER DIEM AT COURSE	___			
TOTAL DIRECT COSTS	___	___	___	
BASE OPERATIONS	___	___		
SUPPORT COSTS				
TRAINING AIDS	___	___		
OTHER	___			___
TOTAL INDIRECT COSTS	___	___		___
TOTAL DIRECT AND INDIRECT	___	___	___	___
TOTAL COST PER GRADUATE	___			

B.1.2 Calculation of Number of Instructors

The number of instructors required in a course is calculated by an automated version of the algorithm listed in the Staffing Guide for U.S. Army Services Schools (DA PAM 570-538).

B.2 PROCEDURAL OVERVIEW

An overview of the procedures in the Resource and Cost Estimation Technique is provided in Figure B-1.

The first step in the application of RCET is the identification of the "reference" course or the comparable existing cousre, which most closely resembles the task and target population requirements of the new course. Procedures for identifying a reference course are contained in the ETES User Guide Manual Procedures. Once the reference course has been identified, cost data for this course is obtained from the Cost Analysis Program (MOS Training Cost) and entered into the SDT.

Reference course information is also used in the construction of the quasi-program of instruction (QPOI) for the new course. Included in the QPOI is a description of the methods to be used in each module in the course, and the student-instructor ratio and instructor contact hours associated with each method. Procedures for constructing a QPOI are contained in the ETES User's Guide. This same guide contains procedures for determining the number of students to be trained. This value is a critical factor in the determination of course costs.

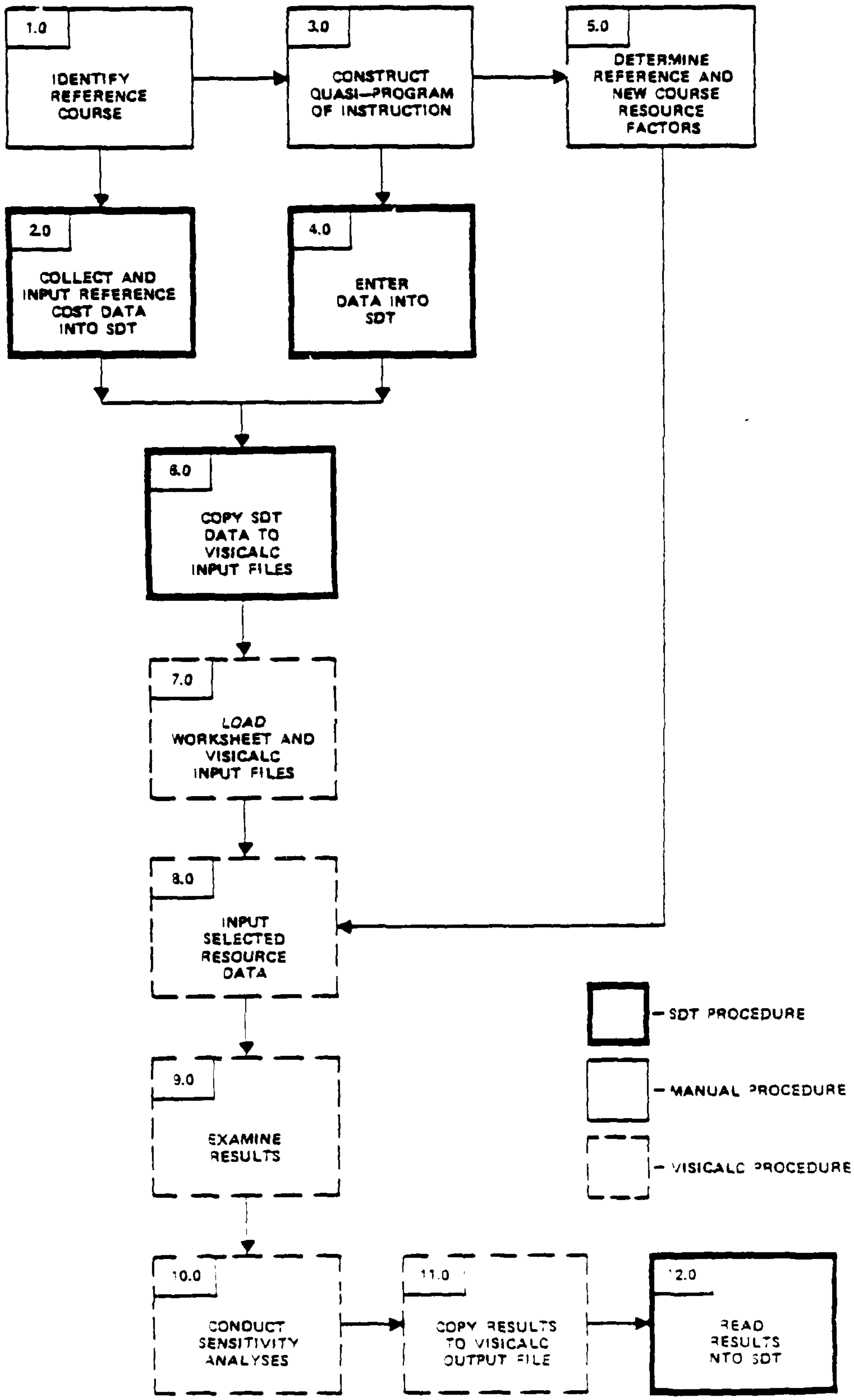

Figure B-1 Overview of Procedures in Resource and Cost Estimation Technique (RCET).

Once the QPOI has been instructed for the new course, information from the QPOI on instructional methods, student/ instructor ratios, and contact hours must be entered into the SDT. When this is completed the the user must enter the SDT, enter the Applications mode, select the Resource and Cost Estimation Techniques (RCET), and copy the reference cost data and new course QPOI data onto files which can be read into the VISICALC program.

Once the VISICALC input files have been developed, the user must remove the SDT software diskette, put in the VISICALC software diskettes and enter the VISICALC program. Once into the VISICALC software, a few simple commands may be used to load the SDT input files and RCET worksheet into the VISICALC. When this is completed, a small selected set of resource data for the reference and new course must be entered into the SDT. Course costs and instructor requirements may then be calculated by executing a simple command built into the RCET worksheet.

After examining the initial estimates of course costs and instructor requirements, the user can then use a few commands built into the RCET worksheet to conduct sensitivity analyses of key parameters. When these analyses are complete, the final set of costs for the new course can be copied onto a VISICALC output file. The user can then exit the VISICALC software, enter the SDT software and copy the output file into the SDT data base.

APPENDIX C: OVERVIEW OF AUTOMATED TRAINING PLANNING AND SCHEDULING TECHNIQUE

This appendix provides an overview of the Automated Scheduling and Planning Techniques (APST). A more detailed description of APST is provided in the <u>User's Guide: Automated Planning and Scheduling Technique</u>. APST is designed to assist training developers in describing and monitoring the training development schedule for developing Army weapon systems. APST is designed to be used with the VisiSchedule software, which is an automated program for describing, monitoring and reporting schedule information and for conducting critical path analyses of schedule events. A data input diskette, describing the events required in the Army's Individual and Collective Training Plan (ICTP), is included in these techniques. This data input diskette contains detailed information on the sequential relationships among the events in the OICTP.

APST is designed to make it relatively easy for training developers to track and monitor the complex relationships among the events in the training development schedule. In addition, by providing an automated capability to monitor the training schedule, it should aid training developers in responding quickly and efficiently to the frequent schedule changes which occur during the development of Army weapon systems.

C.1 CONCEPTUAL OVERVIEW

Construction of training development schedules for emerging systems is a difficult task. Over 100 developmental events are listed in TRADOC Reg 351-9. The sequential relationships among these events are complex and are not described in any systematic and integrated manner in TRADOC Reg 351-9.

Further, the training scheduling process, particularly during the early phases of system development, is characterized by frequent changes and updates. Determination of the impact of these changes is a tedious and time consuming process.

APST contains techniques for using automated VisiSchedule software to track and monitor training development schedule. By using VisiSchedule, the training developer can quickly and efficiently respond to changes in the training development scheudle. Use of the VisiSchedule program is facilitated by the inclusion of an input data diskette which (a) describes the events in the training development process (as specified in TRADOC Reg 351-9), (2) describes the temporal/sequential relationships among these events, and (3) lists the expected duration of these events for a "typical" major Army weapon system. This data diskette significantly reduces data input requirements. In addition, it eliminates the need for an analysis of the complex sequential relationships among training development events which are either implicitly or explicitly specified in TRADOC 351-9.

- Capabilities of VisiSchedule Software

As applied to the training development process, the VisiSchedule software can be viewed as providing the following capabilities:

(1) Allows users to systematically describe an integrated training development schedule including information on training development events, the sequential relationships among these events, the duration of these events, the manpower (by labor category) required to accomplish each event, and the costs (that is, salaries) of this manpower.

(2) Allows users to quickly determine the impact of changes to any of the above information.

(3) Allows users to identify the "critical path" in the training development schedule. A "critical" event is one whose delay would impact completion of the whole project.

(4) Allows user to aggregate events to determine total manpower requirements (by paygrade or occupational specialty) and to determine total training development costs.

C.2 PROCEDURAL OVERVIEW

An overview of the procedures for using the automated planning and scheduling techniques is provided in Figure C-1.

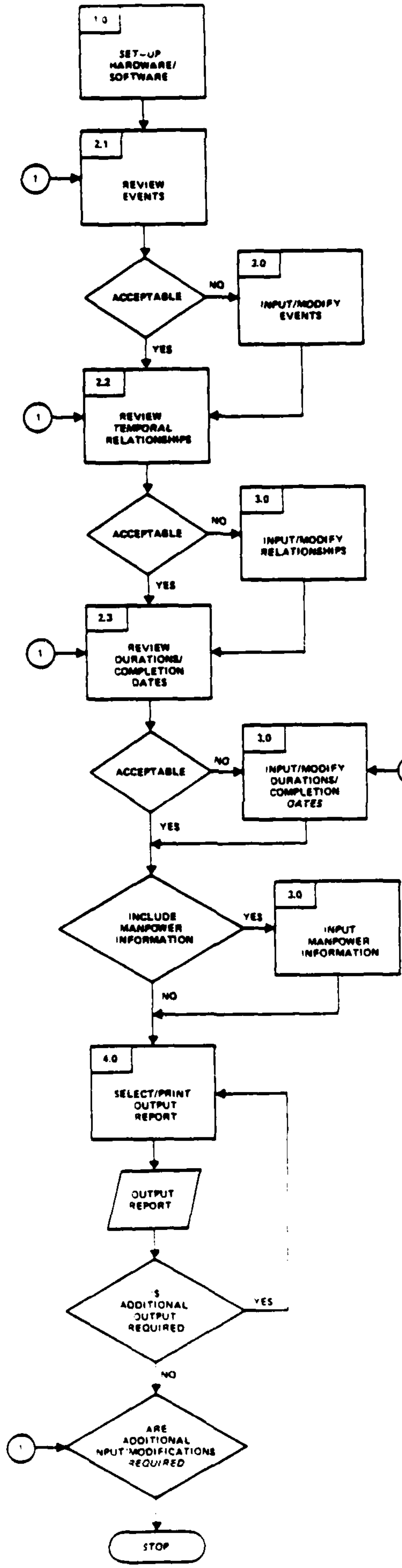

Figure C-1 Overview of Procedures for Using Automated Planning and Scheduling Techniques.

The first procedure involves setting up the hardware and software needed to run the automated techniques. As part of this procedure, the VisiSchedule software and the accompanying input data diskette, describing the ICTP events and their interrelationships are entered into the computer.

In the next three procedures (2.1 and 2.3), the data on the input data diskette describing the ICTP events, their interrelationships, and their durations is reviewed by the user. If the user feels that the existing data is acceptable and, thus, is an accurate description of his/her training development schedule, the user can proceed directly to the output report procedure (4.0). However, it is more likely that the user will want to change the durations or completion deadlines of some of the events; the events themselves and their relationships are less likely to require change.

If changes are required, these changes may be made using the methods described in procedures 3.1 to 3.4. Procedure 3.4 allows users to enter and/or modify data on manpower requirement and costs. Information on manpower requirements must be entered by the user since this information is too system specific to include in the input data diskette.

In procedure 4.0, the user may select from one of four different output reports to describe the training development schedule. After examining these outputs, the user may wish to conduct tradeoff analyses or sensitivity analyses of the schedule input variables. This can be accomplished by changing the input parameters through procedures 2.0 and 3.0.

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APPENDIX D: DESCRIPTION OF PROJECTS RELATED TO ETES

This appendix provides descriptions of the six ARI projects which are directly related to ETES: (1) the Hardware Procurement-Military Manpower (HARDMAN) Methodology, (2) the Man Integrated System Technology (MIST), (3) the Training Efficiency Estimation Model (TEEM), (4) the Training Developer's Decision Aid (TDDA), (5) the Model for the prediction of the effectiveness of Training Devices (TRAINVICE), and (6) the Army Manpower and Personnel Requirements Process (ARMPREP). More details on these six projects are provided in the subsections which follow.

D.1 MILITARY MANPOWER VERSUS HARDWARE PROCUREMENT (HARDMAN)

The HARDMAN methodologies provide the Navy and the Army with a systematic means of estimating human resource requirements (manpower, personnel, and training) during the earliest phases of the Weapon System Acquisition Process (WSAP). The integrated models and data bases of the methodologies are designed to (1) assess manpower, personnel, and training requirements for proposed sytems; (2) determine the impacts of manpower, personnel, and training requirements; and (3) identify and evalute tradeoffs which would alleviate unfavorable impacts. DRC has also extended the capability of HARDMAN through increased automation and the development of proprietary software packages. These advances have significantly cut cost and response time and more closely aligned the output products of HARDMAN with the information needs of Program Managers, resource sponsors and their staffs.

In its present form, DRC's HARDMAN Methodology is composed of six interrelated steps which can be iterated in a timely fashion for the analysis of alternative design proposals. The first step is conerned with various aspects of data collection, generation, formatting, and analysis. It also includes the establishment of an automated audit trail or program record of all input data, analyses and output products. The final five steps involve data evaluation with respect to acquisition program goals and constraints.

The establishment of the consolidated data base triggers the methodology and ensures that all analyses pertaining to a new weapon system use a common data source. Consequently, consistent definitions and collection procedures are employed in assembling data on operator and maintainer functions, the weapon's operational mission/scenario and maintenance concept, its cost factors, and its manpower and training sytem support requirements. The proposed weapon system's demand, in terms of manpower, personnel, and training is determined in Steps 2 through 4 and compared to the projected supply of such resources at system Initial Operational Capability (IOC) in Step 5. Significant shortfalls and equipment sources of high resource demand are identified. In Step 6, the methodology is iterated to examine alternative designs, training methods and media, and total force tradeoffs. Thus the program manager can participate in the design process with a heightened awareness of the training and manpower demands of a new weapon system, thereby ensuring its supportability as well as its mission capability.

DRC's HARDMAN Methodology has been used on a wide range of all three Military Services, including the Shipboard Intermediate Range Combat (SIRCS); the lSD-41, a new class of guided missile destroyer (DDG-51); the Submarine Advanced

Combat System (SUBACS); the Army's Divison Support Weapon System (DSWS); the Corps Support Weapon System (CSWS); and the Remotely Piloted Vehicle (RPV); and in modified form with the Air Force's Combat Identification System (CIS).

These applications have fully exercised all of the analytic capabilities of the methodology. Additionally, they have demonstrated its capability to provide timely, accurate support for program management and review. Specifically, significant or problematic human resource demand generated by equipment design has been targeted early in program development; alternative system and subsystem configurations have been evaluated through tradeoff studies; and the methodology's consolidated data base, supported by carefully documented resource design analyses, has been used to build an audit trail of manpower, personnel, and training assessments and tradeoffs.

D.2 MAN INTEGRATED SYSTEMS TECHNOLOGY (MIST)

The United States Army Research Institute for the Behavioral and Social Sciences (ARI) is developing a technology which integrates manpower, personnel and training (MPT) considerations throughout the Weapon System Acquisition Process (WSAP). Its goal is to ensure the effective planning for and utilization of projected human resources for operational readiness. The technical activity required to achieve this objective has been organized into a major research and development program entitled Man Integrated Systems Technology (MIST). DRC has been selected as the contractor for MIST which is an extensive (5 year, 32 man-years) multi-million dollar effort.

MIST will consist of the necessary technology and management procedures to address the following considerations: (1) the treatment of human resources as a performance and cost factor during system concept formulation, (2) the planning and forecasting of manpower information, (3) the parallel development of associated training systems with weapon systems, and finally (4) the specification of test and evaluation issues to ensure human resource accountability, and to support the ASARC/DSARC review at each of the major development milestones. MIST in particular will integrate and demonstrate the technical relationships among these considerations, and provide the necessary methodology to ensure their effective treatment during the design process from a performance, manpower, training and cost point of view. In addition, MIST will demonstrate how these technical considerations are related and responsive to the Army's Life Cycle System Management Model (LCSMM), and to relevant Army regulations and responsible agencies. MIST will further provide a comprehensive framework for the assessment and integration of other relative technologies and information as they are identified or developed.

When fully developed, MIST will serve as an integrating mechanism providing efficient interfaces for information exchange and feedback among concurrent activities and/or processes involving industry and government, system design engineers and support planners, Army acquisition managers, and the Army's oversight bureaucracies in the Department of Defense and the Congress. Hence, MIST will provide the design and implementation of more comprehensive and responsive data bases and technical/management procedures employed in prime and support system development, acquisition and operation.

When completed, MIST will be composed of three principal components:

- o Analytical Tool Designed to Support Program Managers, TRADOC System Managers, Acquisition Managers (e.g., Weapon System Manager (WSM) in DARCOM), and their staffs/supporting agencies;

- o A system-specific data base to provide a single point source for all man-machine data (input to the tools, output from them and decision support information for program documentation and reviews) collected for an emerging system.

- o A management information system to link MIST users and the data base in an effective communication network within the framework of the Life Cycle System Management Model.

Hence, MIST will provide an important new capability within the Army. This capability is embodied in a cost-and time-efficient system for human resource requirements analysis early in weapon system development. MIST will capture the most recent advances in both man-machine technology and automated data processing to provide a system which is user-friendly at the operational level and responsive to the analysis and information requirements of users at several levels within the chain of command. Finally MIST will "fit into the real world" by providing effective interfaces to existing management information systems and data bases for logistic support analysis, training system development and personnel planning in DARCOM, TRADOC and the Army Staff.

D.3 TRAINING EFFICIENCY ESTIMATION MODEL (TEEM)

TEEM is an interactive computer-based aid designed to assist training developers in early evaluation and generation of training program components. At the foundation of TEEM is a set of psychological variables which reflect the training information contained in a system task description. This is in contrast to the normal textual form in which task descriptions are usually developed. A representation by variables was chosen because early task descriptions are often not in standard formats, may change quickly, and may require elaboration by design engineers or other subject matter experts. A predetermined set of standard psychological variables provided a starting point which could be depended upon for input into the fixed operational code of a computer program.

Initial task groups corresponding to procedures that should be trained together are generated through an algorithm that clusters tasks based upon internal similarity along the psychological variable dimensions. After clustering is complete, a task group has maximum difference between task clusters. The clusters serve as an automated estimate for use during the initial formulation of a training program. Task groups are then modified, if needed, based on the expertise of the analyst or outside mitigating factors such as management and cost constraints that would normally not be included in the psychological variables.

Selection of concrete, costable components such as media and method of training are based upon the similarity of a group of task variable requirements to the ability of a media or method to manipulate psychological variables during

training. Selection is accomplished by representing each training program component by a description in the same set of psychological variables. A task is also coded as a vector of variables with an assocated variable value for each dimension representing applicability or non-applicability. Selection of a program component is performed by automatically matching each task to each potential component and selecting the component with the higher match of critical variables.

If an already existing training component is being evaluated, the matching process is utilized in reverse to generate a figure of aggreement between the theoretical maximum possible under the task and hardware conditions and the actual match under a particular alternative. The normalized numeric value of this match is called the efficiency ratio.

After efficiency ratios have been generated for potential training programs a final selection for the best training approach is made based on pair values of gross dollar costs and their efficiency ratios. Together the values represent an early form of cost-effectiveness ratio for each approach. The best candidate programs are selected for detailed cost analysis through a much more complex accounting program and given increased program specification.

TEEM was constructed with the realities of the early training situation in mind. It does not assume extensive and accurate information. It is "user friendly" with step-by-step guidance to individuals unfamiliar with micro-computers. It is designed to accommodate local school needs and training development procedures without major program

changes. It is also flexible enough to be quickly modified based upon improvements in psychological research and field experience.

D.4 TRAINING DEVELOPER'S DECISION AID (TDDA)*

The Training Developer's Decision Aid (TDDA) was designed to assist training development specialists in applying the Instructional Systems Design (ISD) process. The ISD process is a comprehensive technique for the systems approach to development training. Applied Science Associates, Inc. (ASA), working in collaboration with the Army Research Institute Field Unit at Fort Bliss, Texas, has developed, tested, revised, computerized, and conducted tryouts of the model at five Army schools.

The TDDA is intended to be an aid to training developers who need technical assistance in designing or redesigning training and to streamline the process of making training decisions. The TDDA is procedural in nature; it leads training developers through a series of procedures which specify: (1) what decisions are to be made, (2) a rational order for decisions, and (3) the nature and sources of information required to make valid training decisions. The model also serves to organize and retain information that is gathered and processed during the course development process.

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* Derived from Frederickson, et al (1981).

The TDDS model can be used with partial or complete task lists or performance objectives. It is not necessary to redo the job analysis in order to use the TDDA process. This reflects a training development philosophy that a thorough analysis of the job early in the training development process is essential for making valid training development decisions.

The Job Analysis Module requires the greatest input form subject matter experts (SMEs). Those who hold the MOS being analyzed and selected to serve as SMEs are expected to be expert job performers with at least eighteen months of recent on-the-job experience at an operational site. This is an essential requirement for the successful application of the model. The model is sensitive to quality of the input data and information, since all three major decision (what, where and how to train) are directly tied to input.

There are two separate parts to the SME input in the Job Analysis Module. First, the initial task list is generated by exercising function analyzers. Then, the task list is verified as correct and complete. This should be carried out by a second set of SMEs. At the time the tasks are verified, the remainder of the input information is obtained from the SMEs. The output of this module provides the answer to the question, "What should be trained to prepare someone to perform in their MOS?"

The Functional Learning Requirements Module requires inputs from two sources, MOS SMEs and course development instructor personnel in order to make decisions of how to train. The information generated in this module is used by the course developer to specify the functional characteristics of the

training program. The emphases in specifying these characteristics are on how best to communicate the learning objectives, job context and consequences of task performance, and on providing for efficient practice for acquiring special job skills.

Development of the course requires that the relationships between tasks be determined. The last SME input provides the information for describing these relationships. Tasks are related in three ways. First, the same skills may be required in the performance of different tasks. Knowing which skills are redundant allows for more efficient scheduling and sequencing of instructional elements. Second, some tasks must be performed on the job before other tasks can be performed. For example, a piece of equipment cannot be repaired before the cause of the malfunction is isolated. Or, an intelligence report cannot be prepared before the intelligence information and data are analyzed. The output of these tasks are inputs to the subsequent tasks. The third relationship is merely chronological. One task must be performed prior to a second one but there is not direct output-input dependency. For example, a weapon system has to be emplaced (a collective task) and made ready for action, before it can be used to engage hostile targets, which may or may not occur.

The dependency relationship information is provided by SMEs and is then used to build a task dependency hierarchy. The product is considered to be a general course structure upon which the course map can be built. The task dependency information is generated in the Functional Learning Requirements Module, but is analyzed in the Structure Designation Module.

Information and data from several earlier inputs are used in the last module to .ake decisions as to where the training should be conducted. The task criticality data is one of the primary inputs to this decision. Additionally, the instructional setting characteristics and school context information are used in reaching these conclusions.

The TDDS model then is used to make three major decisions: what to train, how to train, and where to train. Some decisions are made algorithmically and others are heuristically determined.

D.5 A MODEL FOR THE PREDICTION OF THE EFFECTIVENESS OF TRAINING DEVICES*

TRAINVICE is a methodology for the systematic assessment of the characteristics of training devices under development. The model is based on the assumption that certain attributes to be assessed in the training situation will lead to transfer of training to the operational situation. Therefore, the higher the rating on the assessment factors, the higher the transfer that will take place and the more effective the device. The model provides a framework for the making of these judgments. The three variables entering into the assessment are: (1) the transfer potential of the device, (2) the learning deficit to be overcome and (3) instructional effectiveness. As with any model, its effectiveness depends on the adequacy of the input data. Inputs into the model consists of descriptions of tasks and

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* Derived From Narva (1979).

subtasks represented in the operational situation, as circumscribed by the training objective, and those represented in the training device. The controls and displays and their functions for both situations are listed. In addition, the skills and knowledges involved in each subtask in the operational situation are formulated for use in the model. Using these inputs, judgments are made using rating scales. The subtasks in the two situations, operational and training, are compared to ascertain if provision is made for representation of the subtasks in the training device in the commonality analysis. Next, the displays and the controls for both situations are compared on physical and functional similarity. The more similar the display or control in the training device is to the operational situation, the higher the score. This is based on the premise that the greater the physical or functional similarity, the greater the transfer of training that will result. Physical similarity refers to the appearance and physical aspects of the displays and controls involved; i.e., their "fidelity"; functional similarity involved in the operation of control, in information processing terms. The learning deficit analysis is based upon (1) the assessment of the level of proficiency in each skill or knowledge for the students upon entering the training situation, (2) the desired level of proficiency in each skill or knowledge for the students upon leaving the training situation, and (3) tne difficulty (in terms of training time) of training in the skills or knowledges involved in a subtask. This analysis yields a weighted learning deficit for each subtask. The judgments concerning the level of each skill or knowledge are made using scales adapted from Demaree (1961). The last analysis involved in the TRAINVICE model is an assessment of how well the training device adhers to

"good" training techniques. In order to perform this analysis, each of the subtasks is cast into one or more categories of behavior. These categories are those of Braby, et al (1972), which are derived for an earlier behavioral categorization by Willis and Peterson (1961). For each of the behavioral categories represented in the subtask, a list of guidelines, also those of Braby, et al. (1972), are consulted and judgments made of the degree to which the guidelines are followed, or not followed, relative to the manner in which the subtask is represented in the training device. The guidelines are broken up into those dealing with the stimulus, response, and feedback aspects of the training situation. For each subtask, the lowest obtained score on each of the three aspects is used to derive an average training technique score. All of the preceding rating, are then fed into an equation to formulate an index of prediction of training effectiveness, ranging from 0 to 1. This equation is as follows:

$$\frac{(Ci \times Si \times Ti \times Di)}{Di}$$

where C is task commonality, S similarity, T training techniques, and D the training deficit scores for each subtask. The equation was derived from a transfer of training equation of Gagne, Foster and Crowley (1943), which was for use with empirical data, while the TRAINVICE extrapolation deals with judgments made concerning aspects of a device assumed to bring about subsequent transfer of training.

A validation study has been performed on the model, utilizing data obtained during the course of two field studies as criteria against which to compare the predictions derived from use of the model (Wheaton, et al., 1976). The devices were tank gunnery trainers involved with burst-on-target techniques and tracking with the main gun of the M60A1 tank. In each case, the prediction of no differences between the training devices involved was found to be consistent with the equivalence in transfer actually found in utilization of the various devices. This was felt to be a promising but not definitive finding.

In order to obtain additional validation data on the model, and also to obtain experience in utilization of the model to determine if there were aspects that might be changed in order to enhance the practicality of utilization of the model, the Army Research Institute personnel applied the model to two maintenance trainers undergoing evaluation at the Army Ordnance Center and School. This afforded the opportunity to obtain data within a different context than that dealt with by gunnery trainers.

These trainers were concerned with automative trouble-shooting. No difference in training effectiveness was predicted for the two trainers, which agreed with the results of the empirical evaluation. Various aspects of the model which caused difficulty in its utilization were noted and influenced the development of the modified version . In addition, ARI conducted a three-day workshop, in which the developers of the original model and individuals who had utilized the model or had an interest in its utilization participated; this furnished further ideas for possible modification.

D.6 ARMY MANPOWER AND PERSONNEL REQUIREMENTS PROCESS (ARMPREP)

The Systems Manning Technical Area of the Systems Research Laboratory, US Army Research Institute, is promoting a research thrust known as Manned System Integration. One major component of this program is the development of improved procedures for the manpower planning process. The major objective of this proposed research is the development of new, innovative and effective techniques to support the determination of manpower and personnel requirements. ARMPREP will include: methodologies to accurately estimate manpower quantity and skill level of personnel through derivation of behavioral requirements and subsequent translation into Military Occupational Specialty (MOS) and other relationships; techniques to aggregate manpower demand of new systems for comparison with available supply; requirements and attributes of a manpower requirements management information system; and finally, the specification for a computer interactive system. ARMPREP is intended to provide tools for potential integration into the current manpower planning process by cognizant Army agencies. In essence, ARMPREP has four principal components each with its own identifiable research products. These four components are:

- Manpower and Personnel Requirements Determination Methodologies (MANPERS).

- Aggregation Procedures of Manpower Demand (TOTAL MANPERS).

- Requirements for a Manpower Requirements Management Information System (MARMIS).
- Computer Interactive System for determination of Manpower and Personnel Requirements (AUTO MANPERS).

MANPERS

The MANPERS component will provide the techniques and methodologies to formally quantify manpower and personnel requirements. These formal methodologies will aid in the timely and accurate determination of manpower and personnel requirements. In addition, these methodologies are intended to standardize the manpower and personnel requirements determination process to provide information of a consistent nature of use to Army personnel subsystem developers. Specific aspects of the MANPERS component will consist of the following attributes:

(a) The development of a taxonomic model to derive behavioral requirements based upon new system Task Descriptive Data (TDD) and translation of these behavioral requirements into MOS and associated decisions. The model will define the requisite data to be included. This input data will be obtained from sources such as LSA, Task and Skill Analyses (TASA), system requirements and doctrine documents, engineering design data and training plans. The model will specify the level of specificity of data congruent with each phase of the LCSMM. In addition, the model will identify the process by which the behavioral requirements

are derived (i.e., the taxonomy) and the means by which the level of data specifity is embraced by the taxonomy. Finally, the MANPERS methodologies will guide the selection of personnel for a given job in a new system based upon the behavior (or performance) expected of him, as opposed to the current method which involves the preselection of MOS category, previous to and/or without rigorous documentation to support such a choice.

(b) Integration with events and activities of the LCSMM, ILS (LSA) and ISD. The MANPERS process will provide the necessary manpower input to decision makers at critical system development milestones to encourage optimization of manpower planning. Where possible it will support the determination of manpower related life cycle and support costs relative to specific systems. Through involvement with the ISD model, the MANPERS component will support a margin of requirements for new equipment training (of the Material Developer) with training requirements (of the Combat Developer) as identified by specific schools. Finally, the MANPERS component will serve to provide increased accuracy of information used in development of draft plan TOEs (as well as throughout the TOE planning process).

(c) A final aspect of the MANPERS component is the development of a MANPERS manual to include: job aids, examples, procedural models, instrument formats and presentation methods for thorough manpower and personnel requirements determination.

The MANPERS manual will provide a tool for quick responses to needs to generate quality information on a timely and economical basis. The MANPERS manual will facilitate the standardized determination and presentaiton of requirements to increase the utilization of information by decision makers. Finally, the MANPERS manual will provide a competent training tool to producers of manpower and personnel requirements (especially for those new to the job and content area).

TOTAL MANPERS

The TOTAL MANPERS component will provide the techniques for aggregation of manpower demand for comparison with available supply data. Manpower demand is defined as quantity of manpower by quality of personnel (e.g., skill level) both within and across systems. In short, it is a quantity by quality of manpower comparison between demand and supply.

Specific aspects of the TOTAL MANPERS component include:

(a) Development of technqies which can provide quantity by quality loadings of manpower demand for a specific system. The data used by TOTAL MANPERS procedures will be an extension of the basic MANPERS tools by relating some paradigm of personnel performance or behavioral requirements.

(b) Another aspect of this component will be to provide techniques which aggregate information for quantity by quality of manpower across systems through comparison of manpower demand loadings

held in common with personnel performance or behavioral requirements.

(c) A final aspect of the TOTAL MANPERS component will be its coordination with events and activities of the LCSMM, the PPBS (through SACS and TOE planning) and ILS to insure the timely determination of requisite manpower information, and authorizations, as well as changes to force structure and composition.

MARMIS

The MARMIS component will provide the manpower management procedures to integrate the MANPERS and TOTAL MANPERS components with the Army manpower related documentation process. In addition, current manpower management and documentation procedural deficiencies and recommended fixes will be identified. The most significant activity in this component is to support current Army actions in management information systems developments relating to the manpower planning process through the specification of the requirements and attributes of MARMIS. Specific aspects of the MARMIS component include:

(a) Determination of manpower management and documentation procedures to facilitate the utilization of manpower and personnel requirements methodologies and aggregation techniques so as to improve the timeliness and quality of requirements generated.

(b) Identification of means to improve accountability of manpower and personnel requirements documentation to identify potential economies in management and documentation flows. This will take into account organizational and technical complexities which serve to work against desired results. In addition, these efforts will facilitate improved manpower planning as well as to focus upon deficiencies for possible resolution.

(c) Means to control manpower related information will be developed so that many activities concerned with other interests (e.g., LCSMM, SACS and TOE planning, and ILS) can be fully coordinated with, such that appropriate milestone are achieved on a timely basis and the requirements of other activities are met as they relate to manpower concerns.

AUTO MANPERS

The AUTO MANPERS component will provide the basis for development of a computer interactive system for determining manpower and personnel requirements by developing the requirements, attributes and specification for AUTO MANPERS. AUTO MANPERS is intended to provide a basis for MANPERS an TOTAL MANPERS methodologies. Specific aspects of the AUTO MANPERS component will support development of a proposed computer interactive system by addressing the following:

(a) Ease of documentation, update and edit of requirements through use of an online, interactive ADP system which provides: continuous availability to

authorized users, embedded training or job aids, and quick response cross-referencing capabilities with related manpower documentation. These capabilities should lead to increased accuracy and timeliness of requirements production and utilization as well as potential economies in administrative support.

(b) Another potential aspect of this component is the development of a built-in analytic model and mathematical capability to increase the rigor of manpower requirements determination. For example, whenever mathematical calculations or transformations are required the formulas should be readily accessed on the system.

It should be noted that a training device can be considered to be a large system in and of itself. Thus, it has its own associated resource requirements. Estimation of these additional resource requirements is beyond the current scope of ETES. However, it is expected that these resource requirements could be estimated by comparability analysis. Input to the determination of training device resource requirements is provided by the task requirements associated with each device which are determined in Procedure 2.0 and the instructional programs developed during Procedure 4.5.

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APPENDIX E: REFERENCES

ARMY REGULATION	TITLE
1-1	Planning, Programming, and Budgeting within the Department of the Army (MAY 76)
10-4	Organization and Functions, United States Training and Doctrine Command
10-38	United States Army Concepts Analysis Agency (CAA)
11-18	The Cost Analysis Program (DEC 75)
15-14	Systems Acquisition Review Council Procedures (MAY 78)
70-1	Army Research, Development and Acquisition (FEB 77)
70-8	Personnel Performance and Training Program (PPTP) (OCT 78)
70-10	Test and Evaluation During Development and Acquisition of Materiel (JAN 76)
70-15	Product Improvement of Materiel (AUG 80)
70-27	Outline Development Plan/Development Plan/ Army Program Memorandum/Defense Program Memorandum/Decision Coordinating Paper (MAR 75)
71-1	Army Combat Developments (SEP 68)
71-2	Basis of Issue Plan (JUN 76)
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71-5	Introduction of New or Modified Systems/ Equipment
71-6	Type Classification/Reclassification of Army Materiel

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ARMY REGULATION	TITLE
71-7	Military Training Aids and Army Training Aids (OCT 73)
71-9	Materiel Objectives and Requirements (APR 75)
71-11	Total Army Analysis (MAY 80)
310-1	Publications, Blank Forms, and Printing Management
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350-1	Army Training (JUL 78)
350-35	New Equipment Training and Introduction (NOV 81)
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351-183	Service School Training Reports Control Symbol (JULY 76)
570-2	Organization and Equipment Authorization Tables - Personnel (SEPT 78)
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602-1	Human Factors Engineering Program (JUN 76)
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702-3	Army Materiel Reliability, Availability and Maintainability (RAM) (JAN 77)
715-6	Proposal Evaluation and Source Selection (SEP 70)
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TRADOC REGULATION	TITLE
11-1	Manpower Analysis and Force Structuring in Combat Development Forces (OCT 78)
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11-7	Operational Concepts and Army Doctrine (DEC 80)

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11-8	Combat Development Studies (FEB 81)
71-4	TRADOC Standard Scenarios for Combat Developments (MAR 77)
71-5	Scenario Oriented Recurring Evaluation System (SCORES) (MAR 77)
71-10	Integration of the TOE development Process and the Scenario Oriented Recurring Evaluation System (SEP 77)
71-12	Total System Management - TRADOC System Manager (SEP 78)
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350-2	Development, Implementation and Evaluation of Individual Training (FEB 79)
350-4	The TRADOC Training Effectiveness Analysis (TEA) System (June 79)
350-7	A Systems Approach to Training
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	Soldier Analysis (JULY 81)
	TRADOC Training Effectiveness Analysis Handbook

TRADOC PAMPHLET	TITLE
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71-8	Analyzing Training Effectiveness (FEB 76)
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